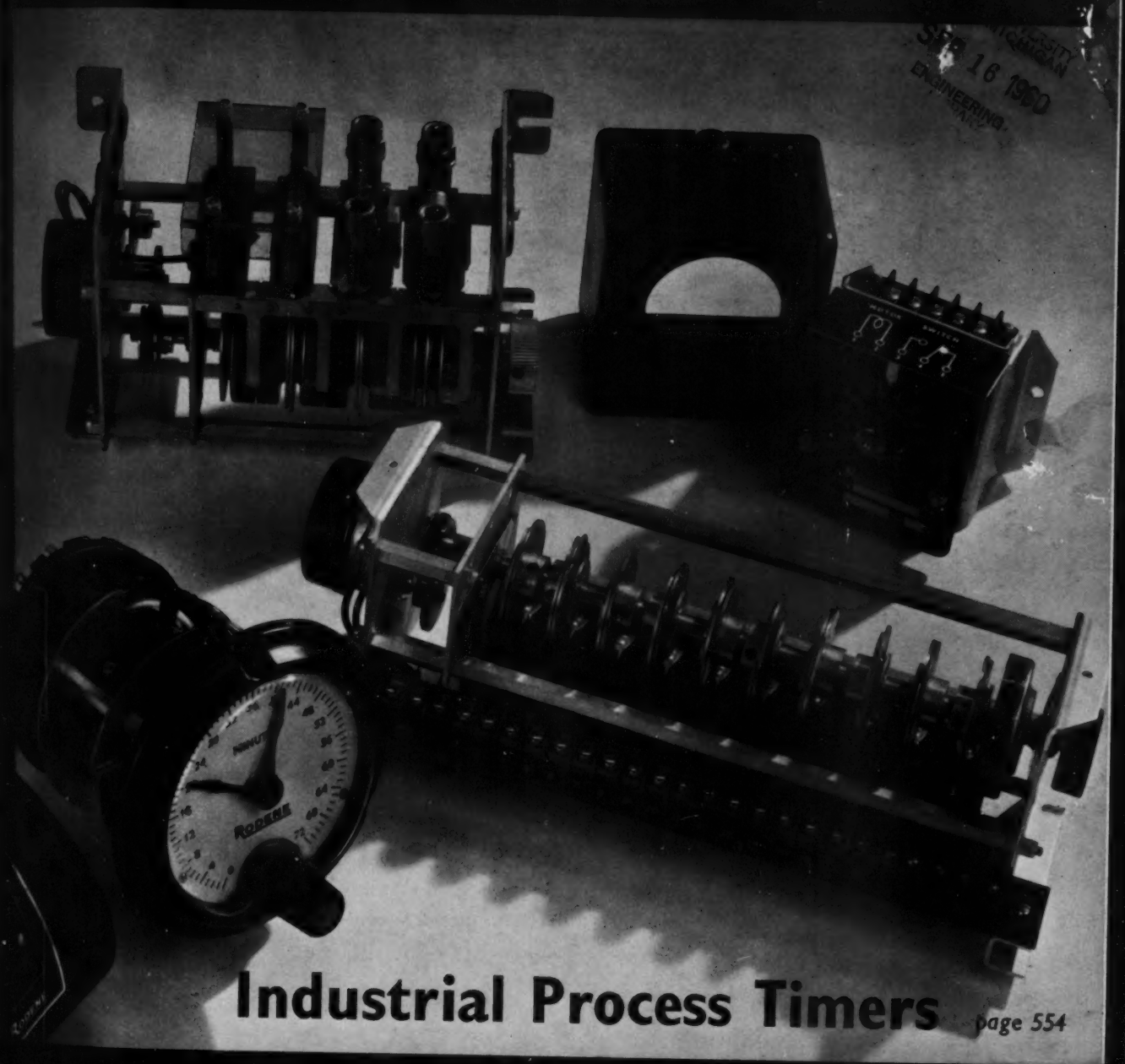
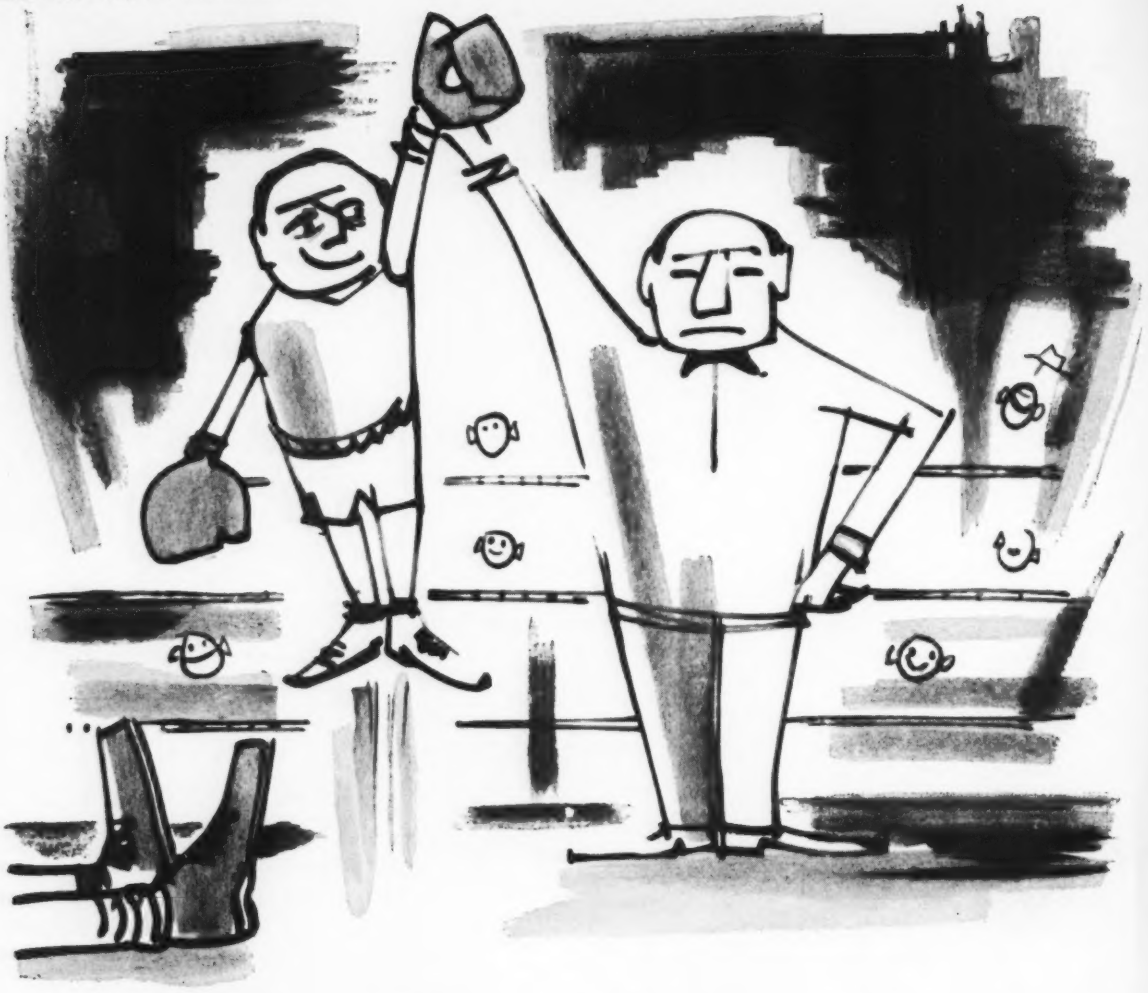
# ngineering Materials and Design




## Industrial Process Timers

page 554

EMD 3403 for further information



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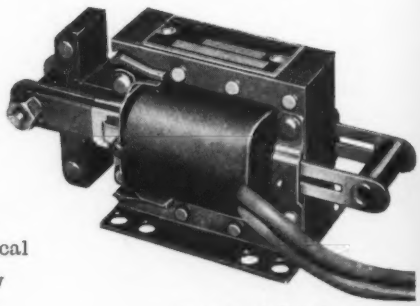

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P 4537

# Engineering Materials and Design

★ *The Magazine for Engineering Designers*

A HEYWOOD PUBLICATION

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COVER: Examples of modern industrial timers: (bottom, left) type 700 instant reset synchronous timer; (top, right) one of a series of self-reset synchronous timers; and two multi-circuit cam timers. (Courtesy of D. Robinson & Co.)


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# Résumés

### RÉSISTANCE A LA FATIGUE DES ALLIAGES D'ALUMINIUM

*W. M. Doyle et I. M. How* page 538

Les auteurs présentent un rapport sur des séries d'essais portant sur deux alliages d'aluminium spécifiques et réalisés avec des tensions directes combinées appliquées à des échantillons forgés ordinaires et à encoches. Ils ont mesuré la valeur des facteurs de réduction de la résistance, pendant des durées bien déterminées, de pièces découpées dans le sens de la longueur et dans le sens de la largeur.

### POLYMÈRES A FLUOR

*Prof. M. Stacey* page 552

Les fluoro-polymères ont des propriétés uniques qui leur assureront probablement une place permanente parmi les matériaux de construction thermiquement stables. Cet article résume les matériaux disponibles à l'heure actuelle et mentionne d'autres polymères actuellement à l'étude.

### SECTIONS RECTANGULAIRES CREUSES

page 546

L'article donne les facteurs qui influencent le dessin des structures et du matériel comprenant des tubes à section rectangulaire. Il fournit quelques exemples des applications réussies de ces tubes.

### CHRONOMÉTRAGE DES PROCÉDÉS INDUSTRIELS

page 554

L'auteur étudie, tout d'abord, les diverses applications des appareils de chronométrage et fournit les données qui permettent de faire un choix correct. Il examine ensuite en détail les divers types d'appareils disponibles.

### CRITÈRES POUR LE DESSIN DES VÉHICULES A COUSSIN D'AIR

page 534

L'article étudie les paramètres de base intéressant les véhicules à coussin d'air par rapport au rendement, au dessus de la terre ferme et de l'eau.

# Kurzreferate

### DAUERFESTIGKEIT VON ALUMINIUMLEGIERUNGEN

*W. M. Doyle und I. M. How* Seite 538

Ein Bericht über Ermüdungsversuche mit zwei bestimmten Aluminiumlegierungen unter kombinierten direkten Belastungen mit ganzen und gekerbten Werkstücken. Die Werte der Festigkeitsverlustfaktoren bei bestimmten Belastungen wurden für Baustoffe in der Längsrichtung und in der kurzen Querrichtung berechnet.

### FLUORHALTIGE POLYMERISATE

*Prof. M. Stacey* Seite 552

Die einzigartigen Eigenschaften dieser Stoffe verleihen den Fluorpolymerisaten eine dauernde Stelle unter den wärmebeständigen Baustoffen. Der Artikel bespricht die heute verfügbaren Baustoffe und erwähnt auch andere, im Entwicklungsstadium stehende Polymerisate.

### RECHTECKIGE HOHLPROFILE

Seite 545

Der Artikel bespricht wichtigsten die bei der Konstruktion von Bauwerken und Einrichtungen aus rechteckigen Hohlprofilen anfallenden Faktoren. Einige Beispiele erfolgreicher Anwendungen dieser kantigen Rohre werden angeführt.

### ZEITKONTROLLGERÄTE FÜR INDUSTRIELLE VERFAHREN

Seite 554

Der Verfasser befasst sich eingänglich mit den verschiedenen Anwendungen von Zeitkontrollgeräten und den zur richtigen Auswahl notwendigen Daten. Im folgenden werden dann die verfügbaren Typen besprochen.

### KONSTRUKTIONSDATEN FÜR LUFTKISSENFAHRZEUGE

Seite 534

Die grundsätzlichen Konstruktionsparameter für Luftkissenfahrzeuge werden besprochen, mit Hinsicht auf ihre Einsatzdaten über Land und Wasser.

# Резюме

### СОПРОТИВЛЕНИЕ УСТАЛОСТИ АЛЮМИНЕВЫХ СПЛАВОВ

*В. М. Дойль и Н. М. Хау* стр. 538

Статья содержит отчет об испытаниях на усталость двух определенных алюминевых сплавов, проведенных под совместным прямым напряжением на гладких и зазубренных кованных экземплярах. Установлены цифровые данные факторов, сокращающих сопротивление при определенной выносливости для материялов с продольного и с короткого поперечного направлений.

### ФТОР СОДЕРЖАЩИЙ ПОЛИМЕРЫ

*Проф. М. Стэси* стр. 552

Уникальные свойства этих материялов, вероятно, предоставят Фторо-полимерам постоянное место среди термально-устойчивых строительных материялов. Статья резюмирует существующие материялы и уделяет внимание другим видам полимеров находящихся сейчас в стадии активного развития.

### ПРЯМОУГОЛЬНЫЕ ПУСТОТЕЛЫЕ СЕГМЕНТЫ

стр. 546

Статья указывает на соответствующие факторы, влияющие на конструкцию структуры и оборудования, использующих трубы прямоугольного сечения. Приводятся примеры успешного применения таких труб квадратного сечения.

### ОПРЕДЕЛЕНИЕ ВРЕМЕНИ ПРОМЫШЛЕННЫХ ПРОЦЕССОВ

стр. 554

Автор статьи рассматривает вначале различные виды использования регулирующих время единиц и информацию, необходимую для правильного их выбора. Затем он подробно обсуждает существующие типы приборов определяющих время.

### ТЕХНОЛОГИЧЕСКИЙ КРИТЕРИЙ ДЛЯ СРЕДСТВ ПЕРЕДВИЖЕНИЯ С ПНЕВМАТИЧЕСКИМИ ПОДУШКАМИ

стр. 534

Обсуждаются основные параметры конструкции средств передвижения с пневматическими подушками, в соответствии с их рабочими свойствами как на земле так и на воде.

# MATERIALS IN THE NEWS

*Monthly Digest of Materials and Design News from Home and Abroad*

## Machine Tool Research

THE STAVELEY RESEARCH DEPARTMENT at Clapham, near Bedford, is claimed to be the only industrial research establishment working on machine tools in Britain. With Dr. E. H. Frost-Smith in charge, the establishment has made rapid progress in its declared object of investigating the basic dynamics of machine tools and the application of automation to them. Various sections are devoted to electronics, servo-mechanisms, mechanical engineering and hydraulics, all supported by design offices and workshops.

On the control side research has concentrated on applying to machine tools the electronic and similar devices used so successfully in other industries, and on developing new ones. Fairly quickly the stage was reached where electronic control apparatus—simplified to do just as much and no more than required—and the associated servo-mechanisms were considered adequate for a big advance in the design of machine tools. But the machine tool itself—on which little research had been done over fifty years—clearly called for investigation into basic structual dynamics and a fundamental approach to problems of kinematic design and construction, particularly in relation to the rather different and more exacting mechanical requirements when electronic controls are applied. As a result of this investigation some major advances are being attained.

Thus, electronics and mechanical investigations are being carried out in the same organisation, and both are directed towards the needs of the machine tool user, leading to new designs in which the automatic control system and the machine tool evolve as an integrated whole.

One aim of Staveley research is to avoid both structural and kinematic weaknesses. On the structural work, the endeavour is to modify the characteristics of the structure in order to eliminate the build up of vibration or chatter due to the cutting process. This involves experimental work on the character and mode of vibrations of machines; also experiments on small plastic models of machine tool structures. This is leading to considerable progress towards securing the optimum design for minimum vibration, and to greater accuracy and better surface finish.

On the dynamic side, since friction, or drag, is a great obstacle to perfection, research led to externally pressurised bearings, and the introduction between all moving members of a film of oil under pressure by means of an external pump. The table of the Archdale Autonomic shown at the recent Machine Tool Exhibition moves on a film of oil, the nearest thing to a frictionless surface obtainable. One result of this is that the power required to move the table is very much reduced, and sticky or jerky motion is said to be entirely eliminated.

## Science and the Modern Army

THE ROYAL MILITARY COLLEGE OF SCIENCE, in addition to being a centre of teaching, also effects research into the sciences and technologies appropriate to the equipment of the Army. It is also the centre of study and information concerning the further application of science to military purposes. One of the principal courses is that taken by officers and by civilians holding scholarships, leading to external degrees in science or engineering at the University of London. Others include post graduate courses in guided weapons, nuclear science and technology, and a course for general and technical staff officers. The majority of the intake to degree courses is composed of officers from Sandhurst who have had varying periods of regimental experience.

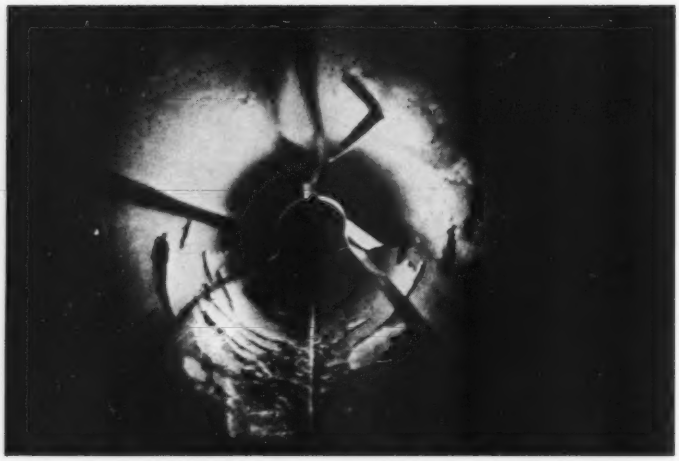
Studies can only be effectively carried out against a background of basic and applied research which is being actively pursued. It was plainly evident that during the recent Open Day the academic training at this College has been very successfully integrated with the precise and methodical background associated with the armed forces. The laboratories, test houses and equipment are kept in excellent condition, polish and perfection being second to none, thus putting to shame many of our older colleges and universities, where untidyness is often construed as synonymous with genius in research. With the background of conventional army training, the methods employed to instruct the students contain many first class working and demonstration models, including those of classic mechanisms like the slider crank and four bar chain.

The problem of fixing turbine blades to the rotor is typical of the type of research studies being undertaken. In general, the failure in fixing a blade is primarily due to vibration, and in an effort to overcome this fixing pins have been angled, recessed and/or tapered, in addition to the conventional fir-tree type of fixing. One of the most successful solutions to this problem has been the use of laminated pins, the vibrations being damped by the friction of one lamination upon another. One interesting thesis being prepared for a Ph.D. concerns the behaviour of tyres under varying degrees of side load. Such experiments are of immense value in predicting not only the wear of the tyre, but the general handling characteristics of the vehicle. Other studies being carried out concern the storing of energy in the chassis of four-wheel-drive vehicles. This is due to a differential tractive resistance between the front and rear pairs of wheels, and can lead to conditions of fatigue and poor handling characteristics.

Towards the end of their studies, students on the technical staff course produce various designs for fighting vehicles in accordance with a given specification, and the most successful of these often lead to a full size mock up, which is considered for utilisation as standard equipment. In addition to the many sectioned vehicles, including Russian and German tanks, a number of completed vehicles are used for demonstration purposes.

In the armament department, full-size working breech mechanisms from almost every conceivable type and make of ballistic weapon are included. Of these the most interesting is that of a large-calibre projectile using a liquid propellant in place of the conventional powder charge. The liquid propellant, being faster burning than powder, causes expansion to take place over a much shorter length of barrel (it is in fact confined to the breech block). The result is a considerably lighter gun barrel.

An investigation which has recently been put into operation is that concerning the effects of shot peening (see *Engineering Materials and Design*, May 1959). The research at present in progress deals with the various parameters of shot size, speed and angle of application, and should provide valuable information for the designer. Strain gauges are used in great numbers on various structural models in the college, and although most of these are of the conventional wire type an acoustic type strain gauge was demonstrated on a beam in bending. A considerable amount of work has been carried out on heat exchangers, in particular one containing rotating tubes. In this, the theory is that the rotation of the tubes, together with suitable baffles, creates vortices which strip off the boundary layer, thereby providing less resistance to heat transfer.



**MOUSE'S EYE VIEW**

This photograph (by Chemring Ltd.), taken from the screen of a closed circuit television system, shows the interior of a gas pipe. Note the intruding pin and deposit of scale. Remote inspection of small bore pipes or cavities, or even under-water objects, is now a practical proposition.

# PICTURE NEWS

## IN THE WORLD OF MATERIALS & DESIGN

**BLUEBIRD DESIGNERS**

Kenneth (left) and Lewis Norris pose in front of Donald Campbell's Bluebird during recent trials at Goodwood. Attempts on the world land speed record with this car are planned for early September.

**LARGEST PAN FEEDER**

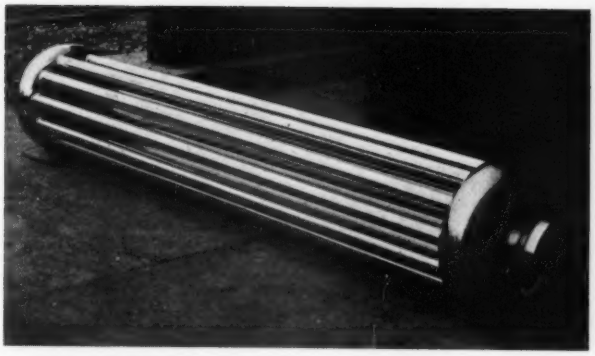
This pan feeder (right), believed to be the largest ever built in the U.K., was made at the Fraser and Chalmers Engineering Works of the General Electric Co. It is designed to carry 200 tons of limestone rock per hour to a crushing plant, in Western Nigeria.

**NYLON ROPE**

Enough nylon yarn to make nearly 350,000 pairs of 15 denier stockings has been used in a large order for nylon rope received by Gourouck Ropework Co. Ltd. The 12-in. circumference rope has a breaking load of 126 tons, and is said to be the largest ever made in Britain.

**ELECTRO-POLISHED STAINLESS**

The Electropol process for stainless steels produces a finished polished surface which is bright and clean and resistant to corrosion. This cooling coil by Electropol Processing Ltd. is part of a polymeriser unit which is manufactured for British Geon Ltd.



**PORTABLE RECORDER**

Shown on the left is the Fi-Cord 101 Swiss precision-made battery-operated tape recorder. Push-button controlled, it takes up less room than a telephone, and is available with a full range of accessories such as lapel microphone, phone recorder (for two-way telephone conversation) and desk stand.

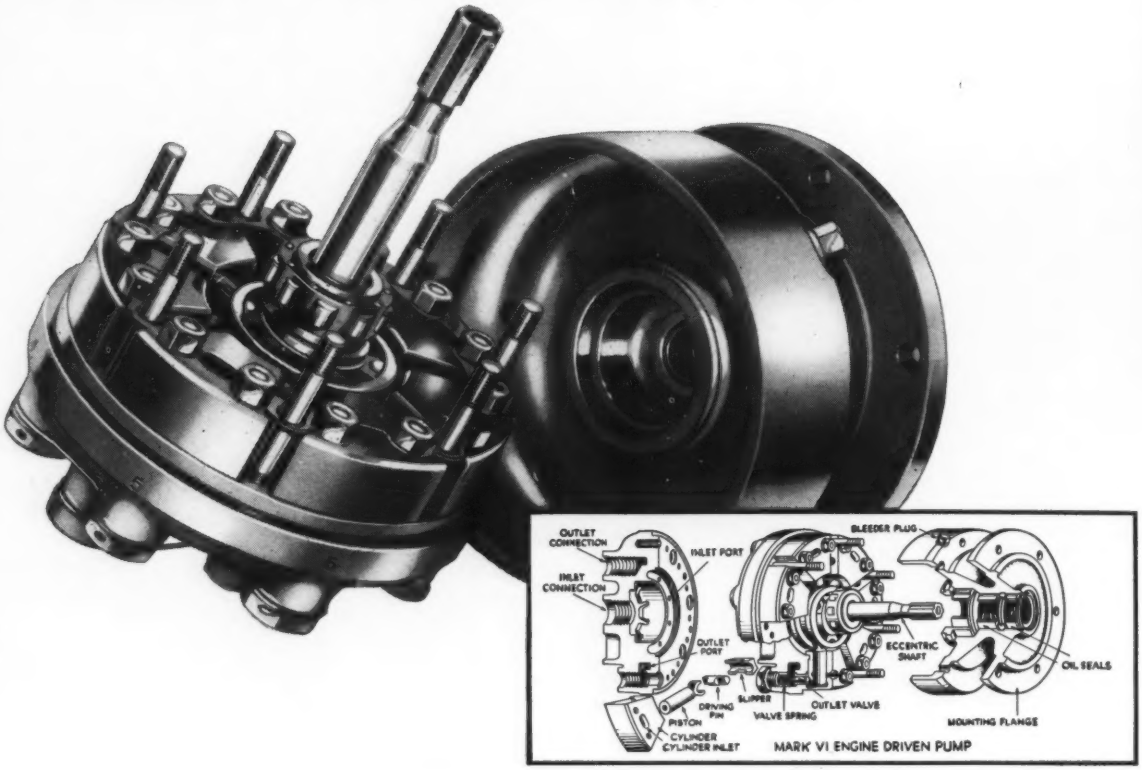
**BRITISH FUEL CELL**

The low temperature cell illustrated above, developed by Shell Research Ltd., is claimed to generate electricity at current densities of 70 amps per sq. ft. when fed with hydrogen and oxygen at 3 p.s.i. It will operate with either alkaline or acid electrolyte. The makers hope to produce multiple units having a power to weight ratio of 50 watts per lb.

**CONTROL BY RADIO**

Accurate operation of cranes is possible with this portable radio transmitter by Demag AG of Germany. The system has obvious possibilities for dangerous sites, where trailing cables make electrical remote control hazardous.

# NICKEL ALLOY STEELS




## ensure reliability in reciprocating units

Lockheed hydraulic pumps, made by the Automotive Products Company Ltd., Leamington, have a world-wide reputation for reliability in the aircraft industry. They are used to actuate flying controls, landing flaps, wheel brakes and undercarriages. Constructional materials are an important factor in achieving reliability in the normal 1000-hour period of operation during which, running at 3000 r.p.m., the plunger operates 174,000,000 times. To withstand the wear associated with reciprocating units, the three per cent nickel case-hardening steel 4S15 (En33) is specified for the cylinders.

TYPICAL CORE MECHANICAL PROPERTIES OF

## EN33

*ARE GIVEN BELOW:*

| SIZE | HEAT TREATMENT | MAXIMUM STRESS t.s.i. | ELONGATION per cent | IZOD ft. lb. |
|---|---|---|---|---|
| $1\frac{1}{8}$" dia. | Oil quenched 860°C. Water quenched 770°C. | 56·3 | 21·5 | 83 |
| 3" dia. | Oil quenched 860°C. Water quenched 760°C. | 47·2 | 20 | 92 |

*The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33; EN 34; EN 36 and EN 39 include ease of heat-treatment, minimisation of processing distortion, and general reliability.*

***Please send for our publications entitled, 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'***

**MOND NICKEL**

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, SW1

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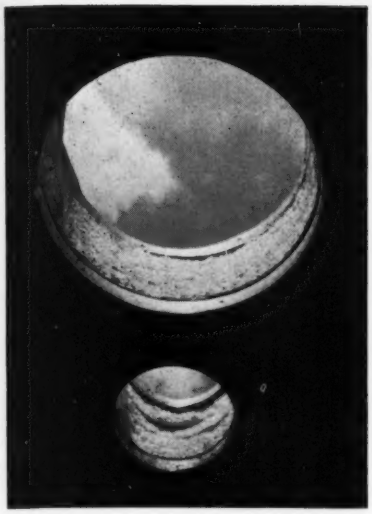
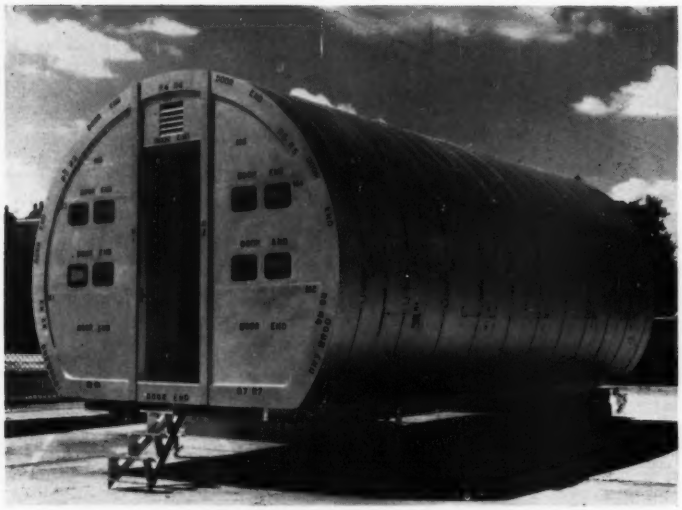




Marleycel expanded polystyrene will insulate Sir Edmund Hillary's Himalayan hut from sub-zero temperatures. The left-hand picture shows the holes which have been left in the roof for the chimney and air-vent.

## Plastic Insulation for Himalayan Hut

NOW ON THEIR WAY by sea to India are the carefully packed sections of a hut, unique in design, which is destined to become the highest building in the world. It will be the home of an expedition being led by Sir Edmund Hillary to carry out physiological research (including a search for the Yeti, or "abominable snowman") on some of the highest unexplored peaks in the Himalayas. The hut will be insulated and protected from sub-zero temperatures by the Marley Tile Company's Marleycel expanded polystyrene, which is made by Shell at their chemical works at Carrington, near Manchester.

The hut will have compact sleeping and living accommodation for eight, and a specially equipped laboratory. It is tubular in construction, similar to an aircraft fuselage, being about 22 ft. long and 10 ft. in diameter. When dismantled, it breaks down into nearly 100 interlocking sections made of thin, tough aircraft plywood on the outside and light plywood internal webbing. Between the two walls is a four-inch layer of Marleycel, which is said to give an insulation value six times higher than that normally found in a brick-built house, and which is also extremely light, weighing only 1 lb. per cub. ft.

The hut will be erected and dismantled at several locations, the highest being at about 20,000 ft., at which height temperatures of about —30 deg. C. (—22 deg. F.) will be encountered. The insulating properties of the walls will therefore play a vital part, and will ensure that the temperature inside the hut will not fall below freezing point, even on the coldest night. Marleycel was chosen as the insulating material after exhaustive tests at the Timber Development Association laboratories, which worked on the project in conjunction with Sir Edmund Hillary.

## Water and Flames

LIQUID FUEL containing 30-50 per cent water cannot be used when the water occluded in it is in the form of sheets or layers, because when the water gets into the nozzle of the burner it extinguishes the flame. Mazut, tars, and other fuels containing water have hitherto been regarded as waste materials, and hundreds of thousands and even millions of tons of waste fuel of this type have accumulated.

A group of scientists at the Institute of Mineral Fuels, Academy of Sciences, USSR, undertook to solve this problem. They have established that if the fuel in which the water is contained is subjected to emulsification by passing it through dispersers or colloidal mills, or by treating it with steam, air, or ultrasonics, this fuel is converted into an emulsion of water in the organic phase. When the water has been dispersed in the form of minute droplets, the fuel burns in any type of furnace as effectively as pure mazut, although it may contain up to 50 per cent water.

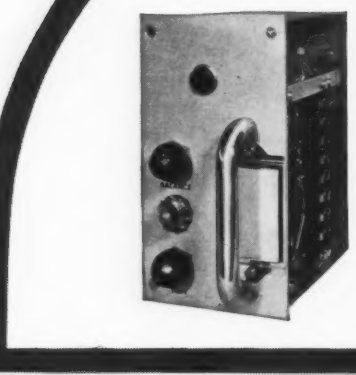
During the combustion of liquid fuel containing emulsified water, droplets of water having a diameter of 1-3 microns are said to expedite combustion by giving rise to minute explosions. These explosions take place because of the difference between the boiling temperatures of the water and mazut. This phenomenon contributes to an intensification of the combustion process, so that the fuel is consumed completely without even the formation of soot. Fuel that contained dispersed water was burned with good results in locomotive furnaces, and on ships. It was also established that by using the procedure described one may dispose of waste waters from factories and plants, instead of releasing them into rivers.

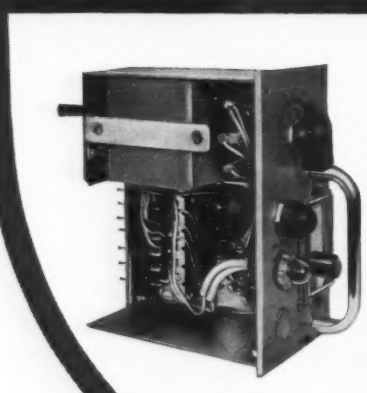
Interesting experiments were carried out on burning water-containing fuels under high pressure, and it was found possible to burn fuel containing up to 90 per cent of water in this way. It was established that combustion under pressure takes place with a very high rate of heat liberation, exceeding by a factor of 1,000 times the rates obtained when combustion is carried out in ordinary furnaces. This opens up great economic possibilities, particularly as far as generation of power is concerned. By using fuel containing water it might be possible to generate steam directly in the furnace during the process of combustion.

## Photo Copying Developments

DEVICES TO REPRODUCE printed matter have existed for many years, but until recently they have required the production of a stencil or a negative. Not only does this increase the time and cost of the process, but in addition wet chemicals are required for development; this not only makes the process messy but increases the amount of maintenance required on the equipment.

In the last few years a number of dry processes have been produced which speed up the process, and which are said to offer great advantages economically. One of the most novel processes of photo copying is that developed by Haloid Xerox Inc., known as xerography. This involves projecting the material to be copied on to an electrostatically charged selenium drum. Where the outline of the printed matter prevents the projector's light from striking the drum, an electrical charge remains after the exposure. A negatively charged ink dust which sticks to the charged areas is applied, and is then transferred to paper which is drawn over the drum. Apart from the simplicity of operation, the process has the great advantage that specially sensitized paper is not required, and copies can be made on ordinary stationery. Any number of copies can be run off at the rate of six a minute. Xerography equipment is available in this country from Rank-Xerox Ltd.





# EMIAC II

## an infinite range of analogue computers

For its price, EMIAC II is easily the most versatile analogue computer available today. It enables the smallest user to order a "one off" computer at a mass produced price, whilst the largest organisation can obtain a general purpose computer or a special simulator of any desired size and characteristics. In every case the user buys only what he needs and receives no redundant equipment. How is this done?

### 'C' Box is the secret

In EMIAC II the same small range of standard amplifiers will add, integrate, multiply, divide, reverse polarity or generate a function. All needed changes are made by the 'C' Box which makes the appropriate connections to the Patch Panel, arranges the corresponding switching and contains the components required for the particular computation. A range of eight 'C' Boxes covers the most frequently used functions. They are readily interchangeable and plug conveniently into the front of the computer. Reserve 'C' Boxes can, of course, be held to extend the computer's versatility. Their small size presents no storage problems.

### The right computer for you

We invite you to let us know your special requirements for an analogue computer. We then suggest the ideal equipment for the purpose, together with any reserve components for secondary applications. Finally we assemble the equipment ready for use. We will be glad to demonstrate the computer and discuss your particular problems.
Full literature on EMIAC II is available.

*On the left, an engineer removes a 'C' Box, two typical examples of which are shown.*

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EMI

EE 34

## Measurements by Radio

THE USUAL METHODS of measuring physical quantities like the strains and temperatures of moving parts require the use of slip rings, flexible leads or intermittent contacts. Such devices have many disadvantages, such as short life or spurious signals, and in order to overcome these difficulties the British Internal Combustion Engine Research Association has developed a transistorised radio telemetering system using small but robust encapsulated units. The system has recently been demonstrated on an engine, with the radio transmitter complete with aerial and batteries mounted inside a piston reciprocating in a cylinder. A heat sensitive transducer varies the carrier frequency, and at the receiving end the frequency variations are converted into a voltage for display on an oscilloscope screen. Similar equipment can be used for measuring pressures, strains, displacements and acceleration.

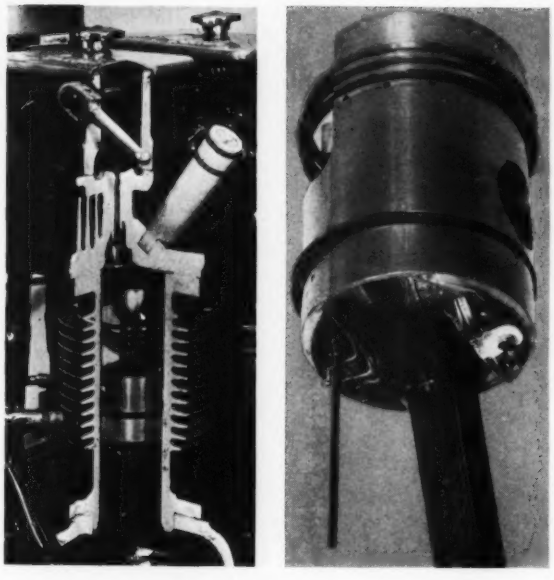
## Problems with Beryllium

THE INDUSTRIAL APPLICATION of beryllium raises many problems, the main ones being concerned with brittleness, manufacture and production difficulties, scarcity and cost, and toxicity. Most research work is directed towards solving the problem of brittleness, it not being yet clear whether this characteristic should be ascribed to either the crystalline structure of the metal, the macrographic structure of the metal, or the impurities.

There are two main solutions concerning crystalline orientations. One is to create a crystalline isotropy through a transformation implying an equivalent degree of deformation in all three directions, and it has been found possible to obtain some improvements by this method—it is not, however, applicable to all forms of product. The second solution is to design in order to make use of the maximum ductility in one direction. Further attempts to improve ductility centre on the metallic and non-metallic impurities. It has also been found that ductility increases with the fineness of the texture of beryllium, and further investigations are being carried out into the possibilities of using still finer powders for the initial preparation of beryllium ingots.

So far, use has been made mainly of conventional manufacturing and fabricating methods, and it would appear advisable for research departments to direct their efforts towards the development of entirely new processes likely to be more suitable to beryllium. Besides the precautions to be taken because of metal toxicity, one of the characteristics of beryllium is its reactivity with oxygen at high temperatures. As its brittleness in a cold state means that it must be worked at high temperatures, an optimum value is therefore important. The primary fabrication processes are forging, extrusion or rolling, and generally these are performed at about 1,000 deg. C. with the metal sheathed in steel. Drawing after extrusion has not proved to be possible, and it is usual to resort to machining in order to obtain accurate dimensions. Beryllium machines somewhat like cast iron, or heat-treated aluminium castings, except that it is more brittle and abrasive.

For the fabrication of beryllium products, shearing, cutting and shaping can be relatively easily carried out at about 500-700 deg. C. under atmospheric conditions, except on very thin products.



(*Left*) Engine cylinder cut away to show a BICERA transistorised transmitter and aerial in position in an engine; (*right*) aerial, transmitter and batteries mounted in a piston.

*THE OCTOBER ISSUE*

of Engineering Materials and Design will include the following main features:

**High-strength 12-per-cent Cr Steels**
Description of the Jethete series of heat-treatable stainless steels.

**Seamless Metallic Bellows**
Discussion of the various uses and potentialities.

**Self-lubricating Bearings**
Survey of plastics which are becoming available for use as bearing surfaces.

**Zinc Die Castings versus Plastics Mouldings**
Explanation of the fundamental advantages and disadvantages of these two types of product.

**Factory Equipment Exhibition**
Review of some of the new materials and designs which are to be shown.

## Plastic Boats in Holland

A NUMBER OF DUTCH SHIPYARDS will display their skill in the use of plastic materials in boat construction at the Macroplastic 1960 Exhibition, in Utrecht, from October 19 to 26 this year. This is a field in which tremendous interest exists on the part of foreign buyers, and there are firm indications that the Netherlands is regarded as an important centre for the building of plastic hulls. Examples of many types and sizes will be on display.

In Holland, two different processes are employed in the manufacture of yachts, motor cruisers and other craft having hulls made from plastics. A distinction is made between those employing polyester reinforced with glass fibre, and those employing reinforced polyester in sandwich form. This typical example of Dutch skill will be among the most attractive national elements in the exhibition. The marine exhibits will be centrally displayed in Hall C, and on the adjacent part of the grounds by the side of the Margriet Hall.

## Awards for Technical Writing

NEW DETAILS HAVE now been published of the ten-year-old scheme now sponsored by the Electronic Engineering Association and the Radio Industry Council, in London, of annual awards for published articles on electronics (with a slant on making known British achievements). Articles published during 1960 by other than professional writers will be considered by a panel of judges. Articles published in trade and technical journals serving user industries are eligible, as well as those in radio and electronic journals.

Six premiums of twenty-five guineas each are offered to the writers of what are judged to be the best articles published between January and December this year. Writers and editors are urged to bring articles (six copies are requested) to the notice of the panel through the Secretary, E.E.A., 11 Green Street, Mayfair, W.1. Any writer is eligible who is not paid a salary wholly or mainly for writing, and who is not earning 25 per cent or more of his income from fees for articles or from book royalties.

## Electric Traction News from the U.S.

A SPECIALLY DESIGNED 72-volt traction motor incorporating high torque per ampere characteristics is being used to drive Eureka Williams Corp.'s new Henney Kilowatt, an electric automobile demonstrated recently at a meeting of the Edison Electric Institute. The Kilowatt uses a single motor, and is said to have a top speed of 35 m.p.h. while fully loaded. The body design is the Renault Dauphine. A completely new stepless electric control is under development jointly by the General Electric Co. and Eureka Williams, but the initial production cars will use magnetic control for battery switching. The range of the new car is said to be between 40 and 60 miles, depending on speed and number of stops. Its weight is just over 1 ton, and it possesses the usual advantages of electric cars, such as easy maintenance and driving.

Built-in battery rechargers will be standard on the production model 'Kilowatt,' and a silicon rectifier will convert the alternating current into direct current to operate the frame-size BT 1344 traction motor. Maintenance consists of keeping the batteries filled, and lubricating nine chassis grease fittings. There is no radiator to fill or to freeze, and no oil to be changed.

Electro Trucks Inc., manufacturers of earth moving and constructional machinery, have announced the availability of a new line of heavy-duty vehicles using four-wheel electric drive. The new vehicles include scrapers, bottom and rear dumpers, and rubber-tyred tractors for pushing and dozing. The 60-ton rear dump vehicle will have a maximum speed of 25 m.p.h., and will be able to turn completely round in less than its own length. The electrical drive eliminates such standard mechanical parts as transmission, clutch, differential and axles.

## Hard Anodising

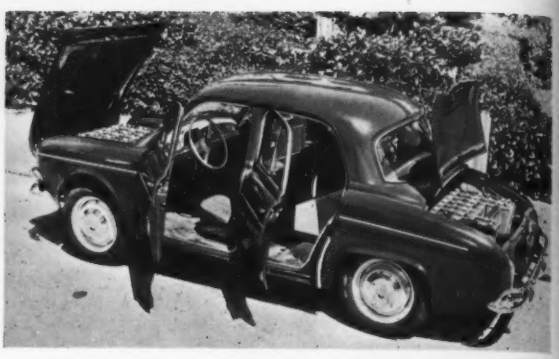
A PROCESS called Alumilite and developed by Alumilite and Alzak Ltd. is a modification of the normal sulphuric acid anodising process, in which the conditions of treatment are altered in order to produce an extremely thick and adherent anodic film. Low temperatures down to minus 5 deg. C., and high current densities of up to 150 amperes per square foot, are used to reduce the effect of chemical attack by the electrolyte on the formed film, and to ensure its rapid formation, so that it is for as brief a time as possible in contact with the electrolyte.

The chemical composition of the film is substantially aluminium oxide plus some chemically bound sulphates. Due to the entanglement of other materials in the film, derived from alloying constituents in the alloys treated, the film is of dark colour, varying from a bronze to a jet black.

On suitable alloys there appears to be no limit to the thickness of film which can be built up. However, in practice it is not advisable to exceed a total thickness of 0.003 in. since the film, although extremely hard, has little or no tensile strength and is liable to sprall off from the surface of very thick films. Such a thickness of film has a sufficient strength of itself to prevent any cushioning effect being experienced from the softer base metal below. Since the film is formed from the material itself and occupies a greater bulk than material from which it was made, an increase in dimensions in the part treated is produced.

The hardest films obtainable are produced on super purity aluminium. Since this material is so soft that it has no value for engineering purposes, such films only have a curiosity value. Such films have a hardness of 800 VPN. In general, on the alloys used for structural purposes, the hardness will vary between 350 and 500 VPN. The hard anodic film is an excellent insulator, giving a breakdown value of 750 volts per 0.001 in. thickness. Impregnated films may be used as effective insulators at a temperature of 250 deg. C. provided suitable impregnating materials are used. It is not possible to insulate properly on sharp corners, edges and very rough surfaces. For optimum results, all corners and edges should be radiused and the surfaces smooth.

The coefficient of friction of the film in contact with steel or brass is high, and the process is not suitable for the treatment of bearings or shafts running at high speeds. The combination of nylon and hard anodised surfaces for bearings is excellent and high loadings may be applied without any apparent wear on either component. The effect on surface smoothness after treatment varies with the alloy, conditions of anodic treatment, and the grain size of the alloys used. Deterioration of the order of from 10 to 50 micro inches can be expected. Corrosion resistance is excellent, provided the film is effectively sealed.



The Henney Kilowatt utilizes the small-car body design of the four-door Renault Dauphine. The motor is located in the rear, directly connected to the gear box and differential.

It is in general not possible to recover wrongly processed parts, since not only is from 0.004 to 0.006 in. of metal removed in stripping, but the lower face of the film, i.e. that in contact with the parent metal, is usually very rough. It is therefore most essential that proper tolerances are allowed in machining before treatment, and that the correct material specification is advised.

The application of the process reduces the fatigue strength of certain alloys by up to 40 per cent, care should therefore be taken in its application to highly stressed parts. Since this reduction in fatigue strength appears to be due to enclosing the ductile aluminium in a hard, brittle shell, and so developing stress concentration at the weaker parts of this shell, it is advisable to apply the process only to that area of a component which will require protection. If the remaining parts of the component are then anodised in the normal manner, i.e. to BS 1615 or DTD 910C, a less brittle envelope will exist and the effect on the fatigue strength will be greatly reduced.

## Corrosion Influences Design

EXPERIENCE HAS SHOWN that poor design of metal objects and structures can lead to serious damage through corrosion. Typical faults that lead to rusting are enclosed areas which form traps for condensed moisture, horizontal surfaces on which water can lie, and design details which cannot be reached for maintenance purposes.

The problem is clearly of practical importance, and the Corrosion Committee of the British Iron and Steel Research Association has, therefore, decided to investigate it. The scope of the research will be wide and will relate to structures and assemblies of all kinds. Moreover, the term "design" will be liberally interpreted so as to include not only design proper and general layout but also the choice of materials and of protective schemes. Structures will first be classified by type and environment; then examples of each type will be inspected from the point of view of corrosion design. Any undesirable features will be listed and practicable alternatives will be checked in consultation with engineering experts, and by experimental work, coupled where possible with service trials. It is hoped that, as a result, a code of recommendations will ultimately be published.

The investigation is of interest to designers and engineers in many fields. Equally, their specialised knowledge and experience would help the investigators, who would welcome suggestions and comments on their proposals. Communications should be addressed to the Technical Secretary, Corrosion Committee, BISRA.

**FOR FURTHER INFORMATION**

Royal Military College of Science, Shrivenham, Swindon, Wilts.
Marley Tile Co. Ltd., Sevenoaks, Kent.
Rank-Xerox Ltd., 33-41 Mortimer Street, London, W.1.
British Internal Combustion Engine Research Association, Slough, Bucks.
Macroplastic 1960 Exhibition, Tesselschadestraat 5, Amsterdam-C.
General Electric Co., Schenectady 5, New York; Electro Trucks Inc., 1933 S.E. Union Avenue, Portland, Oregon, U.S.A.
Alumilite & Alzak Ltd., Priory Works, Station Road, Merton Abbey, London, S.W.19.
British Iron and Steel Research Association, 140 Battersea Park Road, London, S.W.11.

# Engineering Materials and Design

## MATERIALS DEVELOPMENT LAGGING

IN the face of the obvious progress which has been made in the development of new materials during the last twenty-five years, it may seem impertinent to suggest that materials research is behind the times. It does seem, however, that the lack of suitable materials to meet the high performance demands of the space and atomic age is holding up many projects in the fields of atomic energy and high-speed flight.

The effort devoted to materials research is undoubtedly considerable, and it is interesting to speculate why progress has not been faster and what could be done to speed it up. One point which seems fairly clear is that the training and experience of those men who are responsible for developing and applying new materials are not always apposite to the task. It is, we know, extremely difficult to find materials specialists who really deserve their title, and the majority of those we meet are really chemists, physicists or engineers who, after their initial training, have subsequently turned to a study of materials. This is not good enough in a world where specialists must be trained as such from an early age if they are to become skilled and experienced early enough in their career to have a serious impact on their subject. We are not advocating a higher degree of specialisation, but specialisation of a somewhat different kind. In the past materials have been studied in widely separated categories, such as metallurgy, plastics or ceramics, but an expert in one category is usually ignorant of another. Yet the basic properties are the same for all materials, and therefore it is logical to train up the materials experts from first principles and let him study specific types of material only by way of example. If materials were looked at in this way, the vast number of different types available to the engineer might be less confusing and frightening. It might also help engineers to understand the many new materials with properties which are uncharacteristic of their type, such as "ductile" ceramics, "high temperature" plastics and "plastic" metals, so that a correct evaluation and selection for a particular application may be made.

One of our youngest and most virile teaching colleges, the College of Aeronautics, Cranfield, is already teaching materials science in the way we mention, and its department of aircraft materials, under Prof. A. J. Kennedy, deals with the fundamental properties of materials so that students can receive a proper grounding which will enable them to apply their knowledge in any field of materials application.

Another teaching institution, the Northwestern University, at Illinois, recently announced the establishment of one of the first basic materials research centres. This project is not aimed at developing new materials directly, but is intended to uncover new basic information on materials properties and behaviour. Indirectly, this will lead to improved materials, but the point has been made that a graduate materials expert must be familiar with all materials—not just metals, for instance. In designing an end-product it should not matter whether it is made of metal, plastic or ceramics so long as it fulfils its specified function, although in achieving this the economic aspect must not be overlooked.

It has often been stressed that teaching and research should be closely associated, as they are mutually stimulating. In this respect, the new research centre in the U.S. is a step in the right direction, and will undoubtedly help to emphasise the importance of materials study as a subject in its own right. At Cranfield the research side is by no means neglected, and studies of the behaviour of metals under combined stresses (such as creep and fatigue) at high temperature show that they have their sights set high. This college was only founded in 1946, and therefore it is too much to expect that it will be able to carry on its shoulders the whole responsibility for training all the materials engineers who will be needed. It would be encouraging to see some of the older and larger colleges and universities adopting a similar policy.

The Editor

Fig. 1. Latest version of the Saunders-Roe hovercraft.

# DESIGN CRITERIA FOR AIR CUSHION VEHICLES

*The hovercraft and its future development has caught the public eye—the following article illustrates some of the fundamental design problems and their solutions*

BASIC design theory is continually being revised to predict more accurately the performance of air-cushion vehicles The following extracts from three technical papers[1, 2, 6] show the trend of recent investigations in the United States.

The basic objective of a recent study was to illustrate the potential of the air-cushion vehicle as a means of transportation. There are two distinctly different air-cushion techniques that may be utilised in the design of a transport system.

One technique is to utilise an air-cushion as a means of supporting a vehicle over prepared surfaces, such as a rail or road system with very close clearances. In this role, the air-cushion acts as a low friction lubricant. This application offers the potential of a safe, efficient, high-speed means of transportation. This technique is often referred to as the levapad or air-bearing principle.

The other basic concept of the air-cushion principle is a means of transportation over all types of unprepared terrain. In this concept, a cushion of low-pressure air supports the vehicle above the ground. The annular jet and plenum chamber typify the current approach to this technique. This method offers the potential of operations over all forms of unprepared terrain such as water, snow, mud, ice, etc., if sufficient clearance is provided.

### Quantitative Evaluation

In any quantitative discussion, it is necessary first to settle on a frame of reference, and that suggested by H. Chaplin[2] appears to be the most useful. Chaplin suggested the use of a reference aerodynamic lifting system operating out of the ground effect, so by means of simple momentum considerations the lift and power required can be defined as the "ideal hovering lifting system" and the "ideal hovering power required", the latter being equal to

$$\frac{W}{2\sqrt{\rho}}\sqrt{\frac{W}{S}},$$

where W = weight; S = surface area; and $\rho$ = air density.

The concept, then, is to define the power required for the annular jet and the plenum chamber in terms of this reference power, and further to show how the power required varies as a function of the height of the vehicle above the ground.

Annular jet type air-cushion vehicles confine the bubble of low-pressure air beneath the machine by means of a jet of air exhausted around the periphery of the vehicle. The pressure level of this cushion of air is dependent upon the force balance between the pressure forces in the air-cushion and the centrifugal forces associated with the resulting outward deflection of the annular jet.

The theoretical hovering power requirement for the annular jet may be expressed as $G\left[\frac{W}{2\sqrt{\rho}}\sqrt{\frac{W}{S}}\right]$ where G depends upon height, planform area S, perimeter $l$, jet area Sj, jet angle $\theta$, and jet momentum J (see Fig. 4) and

equals $\dfrac{\sqrt{1+\frac{Sj}{Sb}}\left[\frac{1}{\sqrt{\frac{Sj}{Sb}}}+\sqrt{\frac{Sj}{Sb}}\cdot\frac{1-\sin\theta}{\frac{h}{S}\sqrt{1+\frac{Sj}{Sb}}}\right]}{\left(\cos\theta+\frac{1-\sin\theta}{\frac{h}{S}\sqrt{1+\frac{Sj}{Sb}}}\right)^{3/2}}$

The pertinent variables are illustrated in Fig. 4. As written, it is apparent that the required power is given by the function G times the power required for the reference lifting system operating out of ground effect. The term G is defined as the "theoretical hovering ground effect power factor" and represents the reduction in power requirements that can be achieved by operating in close proximity to the ground.

The principle of operation of the plenum chamber air-cushion vehicle (see Fig. 5) is to maintain a cushion of low-pressure air within the plenum by means of an actuator or fan system. This cushion of air, which supports the vehicle above the ground, will leak out around the periphery of the vehicle, the equilibrium height being established when the flow in through the actuator is equal to the flow out around the periphery.

The analysis of the power requirements of a plenum chamber uses the same momentum principles used in the annular jet theory. The power required is given by the volume flow times the pressure rise, i.e.

$$P_T = \left[ 2{\cdot}83\ C\ \frac{h}{S/l} \right] \frac{W}{2\sqrt{\rho}} \cdot \sqrt{\frac{W}{S}}$$

Thus, in a manner similar to the annular jet, the power required for the plenum chamber may be expressed as a theoretical hovering ground effect power factor, G, times the power required for the reference lifting system. The variation of G with height is shown in Fig. 6 for various values of the discharge coefficient C. Although two-dimensional theory indicates that C = 0·6, if it can be reduced by some type of aerodynamic spoiler to the value of 0·38 then the power required

$$P_T = \left[ 1{\cdot}09\ \frac{h}{S/l} \right] \frac{W}{2\sqrt{\rho}} \cdot \sqrt{\frac{S}{W}}$$

The advantage of the use of G is that it illustrates the ground effect phenomena which permits hovering with less power. Fig. 6 demonstrates, quite simply, that to operate at power requirements substantially lower than those required for flying, the air-cushion vehicle must operate at low values of $\frac{h}{S/l}$

The above theoretical hovering power requirement is only part of the design consideration. The relative efficiency of the ducting, inlet, and fan or actuator system must be given very careful consideration.

The limited test data available[2, 3] indicate that these simple momentum theories are really very good, and such factors as viscous effects represent only minor additional power requirements. A typical result is that these simple momentum theories will predict the power required within 10 to 20 per cent.

The losses involved in ducting the air from the fan to the exit present a serious problem, and unless careful consideration is given the overall ducting efficiency may be so poor that the vehicle may not be feasible. The losses will be of the order of 10 per cent even when extreme care is exercised. Another serious consideration is the conversion of shaft power into aerodynamic power at the actuator or fan. Even with careful attention to blade design details, it is difficult to achieve an efficiency of 86 per cent. Summarising, it is believed that an efficiency factor of 70 per cent can be achieved in a well-designed system.

The large reductions in power required as the size increases will be evident from the fact that the lift generated is dependent on the area of the planform, which increases with the square of the diameter, while the perimeter, which determines the power required, varies directly as the diameter.

In any consideration of the thrust and drag characteristics of air-cushion vehicles it is necessary to outline the definition of thrust and drag. In the case of air-cushion vehicles it can be very confusing, because the air which in forward motion has a momentum parallel to the path of motion is brought on board and then exhausted out the bottom in a vertical or near-vertical direction. The limited amount of test data available indicates that the air power conditions at the exit of the vehicle necessary to maintain the lift are independent of forward speed.[3] Therefore, the lifting system is required to put energy into the system at the same rate, independent of velocity.

If the vehicle is streamlined to a high fineness ratio, the profile drag coefficient can be reduced to the point where it is composed primarily of the skin friction drag, which is of the order of 0·005, based on the planform area S. In order to achieve such a low drag, the planform shape will be very poor from the lifting aspects, and the power requirements for lift will be extremely high.

The power required for lift can be minimised by utilising a circular planform and, as a consequence, the profile drag will be high. This profile drag will be composed primarily of pressure drag rather than friction drag, and can get extremely high, depending upon both the frontal area and the base area of the vehicle.

To permit an evaluation of the air-cushion vehicle as a

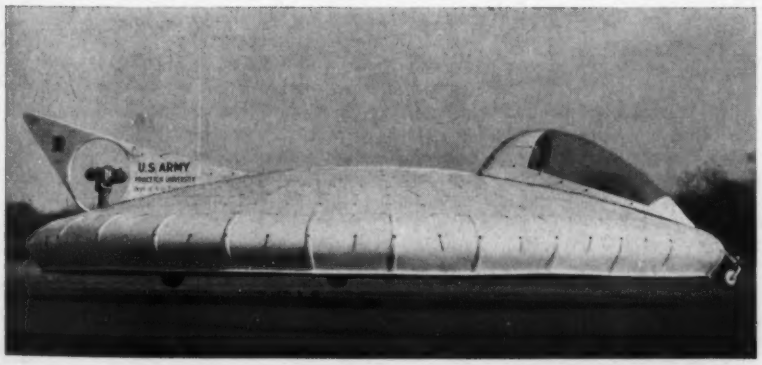



Fig. 2. Twenty-foot-diameter ground-effect machine, showing wool tufts for indicating air flow.

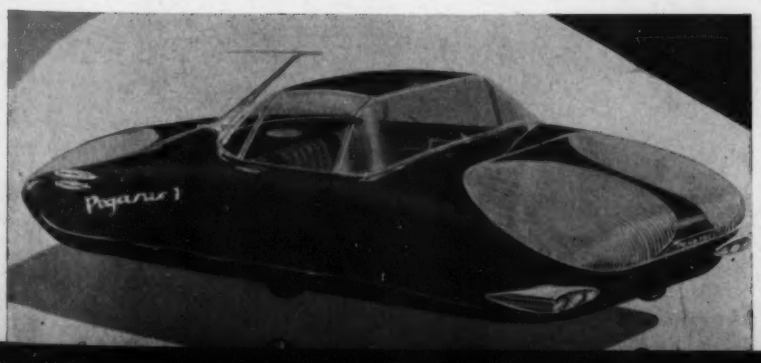
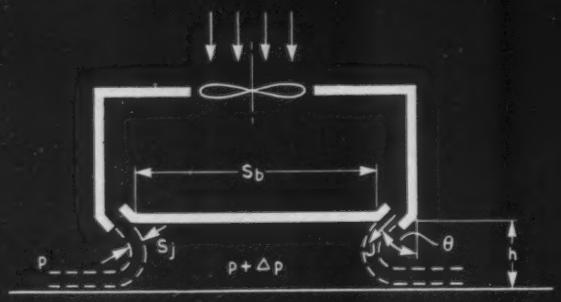
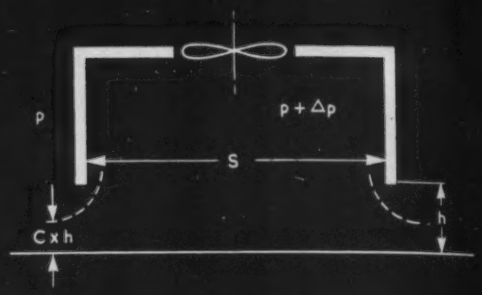



Fig. 3. Pegasus 1 ground-effect vehicle, made by National Research Assoc. Inc. The body shell is an epoxy glass fibre laminate on an aluminium alloy torque box, and the power unit a Triumph twin-cylinder o.h.v. air-cooled engine of 40 h.p.




means of off-the-road transportation, it is necessary to present some drag data that can be considered typical. Fig. 9 illustrates the horsepower per ton of gross weight to provide some estimates of power required to overcome drag. These power requirements are shown as a function of speed and planform loading. A spread in profile drag coefficients from 0·05 to 0·1 based on planform area is considered to represent a typical variation. It is worthy of note that these drag coefficients, by aviation standards, are relatively high.

**Comparative Aspects**

A summary of the payload power requirements indicates that the wheeled vehicle, although it represents relatively low power requirements per ton of payload, is severely restricted in the terrain that it can traverse. Further its mobility is restricted due to speed limitations. The aircraft offers relatively good horsepower per ton of payload characteristics and excellent high-speed characteristics. However, because of its dependence on prepared take-off and landing facilities, it represents a system that is very inflexible in its initial and terminal points of operation.

The helicopter presents excellent characteristics in its ability to operate over all types of terrain. This vehicle can get into and out of more places than any other form of transportation. However, it is restricted in its range capability due to high power requirements, which are reflected in the high horsepower per ton of payload which is necessary.

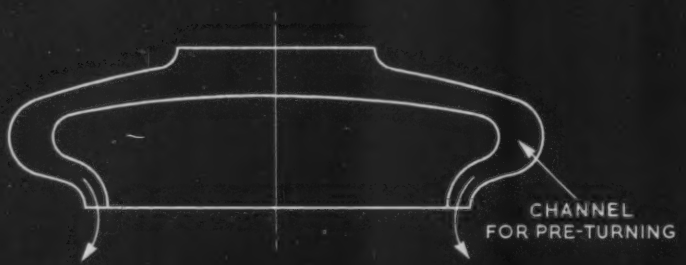
The horsepower per ton of payload for air-cushion vehicles varies so widely with the operating conditions that it is difficult to generalise. However, it would appear that, performance-wise, these vehicles offer a tremendous increase in off-the-road capability as compared to the wheeled vehicle. Further, the air-cushion vehicle can in some cases offer payload power requirements competitive with or better than aircraft, and it is not dependent upon fixed terminal installations like aircraft. Admittedly, the air-cushion vehicle is more restricted in its operation over some types of terrain than the helicopter, but it offers the potential of reduced power requirements.

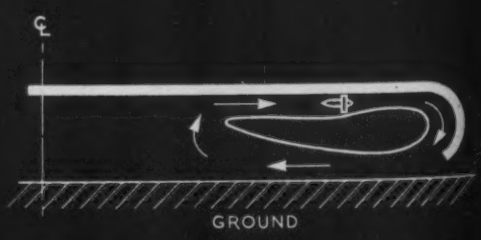
**Over-water Aspects**

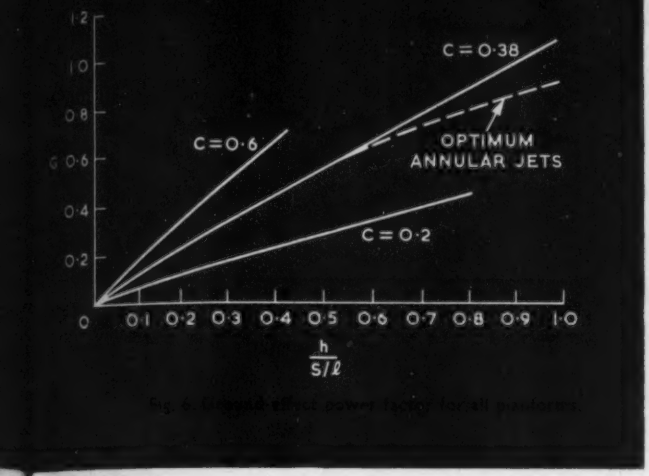
The large thrust augmentation obtainable with annular-jet configurations due to ground proximity can be obtained only at very low heights in the order of a few per cent of the diameter of the vehicle. To take advantage of this thrust augmentation, therefore, the vehicle must be either very large or must operate over very smooth terrain. Over-land uses of these vehicles then will probably be rather limited.

In considering the over-water application of ground-effect vehicles some knowledge of the surface conditions to be encountered is necessary. Water, of course, seeks to maintain a smooth surface, but the action of the wind, however, can create very high waves in the open sea, these wave irregularities being statistically known. The effects of operating over water in hovering are primarily the generation of a large amount of spray and a reduction in hovering height for a given weight due to the displacement of the water by the base pressure. The spray problem, however, can be reduced appreciably by the addition of spray deflectors.

Inherent attitude stability is a function of base-plate configuration, but, in general, over land it is limited to heights of 10 per cent of the diameter or less. The stability charac-






teristics change appreciably over water, and the stability characteristics of any vehicle expected to operate over water should be investigated in model form in over-water tests.

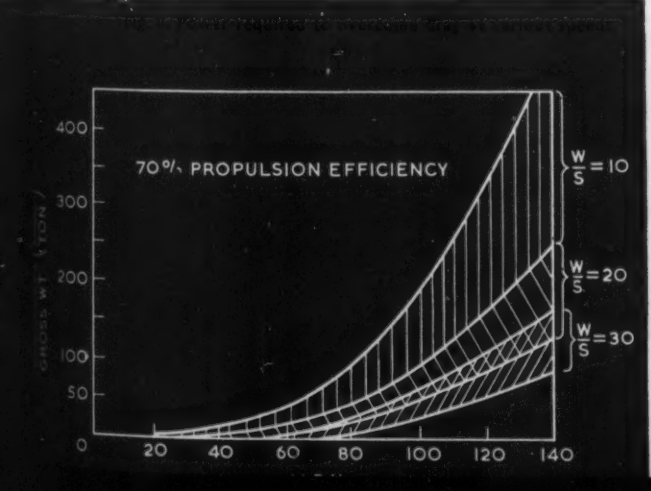
At low forward speeds over water, the ground-effect vehicle tends to trim in a nose-up attitude, due to the slope of the displaced water surface beneath the configuration. As speed is increased the nose-up trim reaches a peak, and with further increase in speed the trim angle decreases. A drag force will be experienced due to nose-up trim because of the rearward inclination of the lift vector.

Operation of the ground-effect machine at forward speeds over swells results in a vertical oscillation of the vehicle; this is greater than the wave height at frequencies approximately equal to the natural frequency of the vehicle in vertical motion. At speeds where the wave frequency is greater than the natural frequency, the amplitude of vertical motion decreases rapidly.

Although large thrust augmentation can be obtained in hovering, the inlet momentum drag of the air required to produce the jet results in relatively high drags at forward speeds and relatively low lift-drag ratios. The inlet momentum drag will probably have to be reduced by transferring some of the lift to something approaching aeroplane-type wings (to reduce the jet thrust and base lift required), if reasonably high speeds and long ranges are required.

**Propulsion Aspects**

The ground-effect machine concept has introduced a new and unique "propulsion" requirement—that of establishing and containing a high-pressure air bubble under the base of the vehicle for both hovering and forward speed conditions.




It has been demonstrated that the ground-effect machine has an extremely attractive lift-to-horsepower ratio capability. In addition, there are certain possibilities for improving this capability.

From a propulsion standpoint, the ground-effect machine (g.e.m.) problem can be divided into two parts. The first is concerned with establishing and containing a base pressure under the vehicle greater than atmospheric. The second is concerned with providing the thrust for forward motion. Of the two, establishing and containing the "pressure bubble" represents a new requirement which did not exist before the g.e.m. concept. The problem of providing thrust for forward motion might be considered as essentially conventional, that is, stable forward speed will be obtained when the horizontal component of the thrust is equal to the drag of the vehicle. However, the problem of maintaining the high base pressure under forward speed conditions is an important corollary problem which must be considered.

No serious effort has yet been expended to exploit the possibilities of aerodynamic lift where, given the large surfaces available in the g.e.m. and the forward velocities currently being considered, significant lift forces can be obtained efficiently, thus actually relieving the ground cushion lift required at forward speed. One can extrapolate even further, and anticipate that as forward speed continues to increase the device will eventually become a flying machine, and the g.e.m. concept will be used primarily for take-off and landing. Such an approach is already receiving consideration.

It is anticipated that considerable effort will be directed in the future to the problem of reducing the horsepower required to maintain the high-pressure air-cushion. One possibility is called the "Hiller Jet Diffuser Recirculation Concept". In essence, a recirculating air flow (see Fig. 8) similar to that which exists in a wind tunnel is established. The static pressure of the air in the region of the flow system open to the atmosphere is also at atmospheric pressure, and consequently there is no tendency for the air to flow out. The air is then diffused, thus producing the high-pressure bubble under the machine. Since the same air is continually recirculating, some form of cooling may be required, but this is not expected to be an important problem. The only power required will be that necessary to overcome the losses in the system and to maintain the air flow.

An interesting air seal configuration intended to ensure a stable free-vortex flow at the nozzle exit is shown in Fig. 7, and it is believed that this offers promise.

Summing up, it would appear that the eventual acceptance of the air-cushion vehicle as a means of off-the-road transportation will depend upon the ability to achieve these attractive performance characteristics with a vehicle that is safe, reliable and easy to operate and maintain. This will require the development of an adequate control system, and inherently good stability characteristics. Further, acceptable solutions to the operational problems of dust and spray must be found.

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2. H. Chaplin and B. Stephenson, "Preliminary Study of the Hovering Performance of Annular Jet Vehicles in Proximity to the Ground", David Taylor Model Basin Aero Report 947, August 1958.
3. A. A. Tinajero, "Effect of Vehicle Planform on Performance", presented at Symposium on Ground Effect Phenomenon, October 21-23, 1959.
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6. R. W. Pinnes (Bureau of Naval Weapons, Washington, 25, D.C.), "The Propulsion Aspects of Ground Effect Machines", paper presented to the Institute of Aeronautical Sciences.
7. A. L. Haynes and D. J. Jay (Ford Motor Co.), "Sliding on Air", presented at S.A.E. Annual Meeting, January 11-15, 1960.
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# NOTCH FATIGUE PROPERTIES OF SOME HIGH-STRENGTH ALUMINIUM ALLOYS

*In this article the authors present a comparison between the notch fatigue strength of large slabs forged in BS L77 and DTD 5024 type materials under combined direct stresses*

by W. M. DOYLE, Ph.D., M.Eng., F.I.M., and I. M. HOW, B.Sc. (Eng.)*

IN view of the increasing demand from the aircraft industry for fatigue test data relating to the high-strength structural aluminium alloys, an investigation has been undertaken to determine the relative notch fatigue strength, in the longitudinal and short transverse directions, of large slabs forged in Hiduminium RR77 (to DTD 5024) and an alloy EX437 conforming to the composition of BS L77 but differing from the latter in the quench conditions, which are described later. Direct stress fatigue tests have been carried out under a wide range of mean tensile stress on both plain and notched specimens, and the results compared using Gerber-type diagrams in which the nominal semi-range of alternating stress is plotted against mean stress. This comparison has been made at endurances of $10^4$ and $2 \times 10^6$ cycles, these values having been selected as representative of those near the lower and upper limits of the range of life required under service conditions.

A method of determining the effective strength reduction factor has been employed which, it is suggested, takes into account the effect of the mean stress on the notched specimens. This assessment of notch sensitivity is considered to be a logical extension of the theoretical construction developed by Gunn[1] for predicting the fatigue performance of notched test pieces subjected to combined direct stresses, and it has provided a further basis for the comparison of the two alloys.

### Material Tested

The slabs used in this investigation measured 15 by 7 by 48 in. Each slab was divided into two parts 24 in. long, from which blanks were cut 1¼ in. square and 6 in. in length, prior to heat treatment. The blanks were obtained from the longitudinal direction of one half of each slab and from the short transverse direction of the other half, it being possible to machine four fatigue test specimens or one standard tensile test piece from each blank. The cross-sectional area of these blanks was similar to that

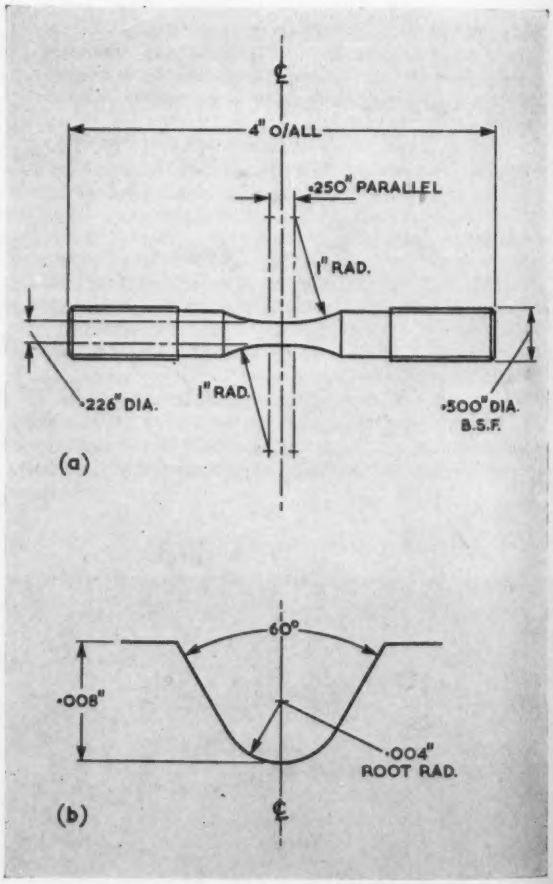


Fig. 1. Test pieces used in the fatigue tests: (a) Haigh fatigue test piece (plain), and (b) detail of notch ($K_t = 3{\cdot}4$).

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of many large components, and it was decided to heat treat the material at this stage according to the following schedules:

| | *Hiduminium RR77* | *EX437* |
|---|---|---|
| Soln. treat | 4 hr. at 465 deg. C. | 4 hr. at 505 deg. C. |
| Quench in | Boiling water | Boiling water |
| Ageing | 12 hr. at 135 deg. C. | 6 hr. at 185 deg. C. |

While it was realised that the level of tensile properties of EX437 resulting from such a quenching treatment would be below the BS L77 specification minima, the boiling-water quench was incorporated in order to produce comparable conditions of minimum internal stress in both alloys, since it has been demonstrated experimentally by Rosenthal and Sines[3] that the presence of residual tensile stresses in fully heat-treated material is detrimental to good fatigue performance. These workers used notched specimens which had been preloaded in order to induce either residual tensile or compressive stresses. On the other hand, the improvement in fatigue strength due to the residual compressive surface stresses associated with shot peening or surface rolling is well known.

It is generally assumed that materials possessing a low value for the 0·1 per cent proof stress/tensile strength ratio may be expected to exhibit a superior notch fatigue strength to those with a high proof/ultimate ratio. This is based on the assumption that a material which is capable of deforming plastically under cyclic stresses, with the consequent partial relief of the stress concentration, will be less notch sensitive than other materials. The adoption of the boiling-water quench after solution treatment for the two alloys investigated produced a value for the 0·1 per cent proof stress/tensile strength ratio of approximately 0·9 for the Hiduminium RR77, compared to one of approximately 0·75 for the EX437, and it was considered to be of interest to assess the fatigue strength and sensitivity to stress raisers of such materials.

CHEMICAL COMPOSITION—Representative samples which were collected during the machining of test pieces after heat treatment were chemically analysed, and the results are given in Table 1.

TENSILE PROPERTIES—Tensile tests were carried out on standard test pieces 0·564 in. in diameter, the average results of eight tests from each direction being given in Table 2. The tensile strength of specimens taken from the outside of the Hiduminium RR77 slab, in the short transverse direction, was 2·5 t.s.i. greater than that of those from the central areas. In the case of the EX437, this difference was only 1 t.s.i., the higher-strength material again being that near the outer edges of the slab. The results of tests on longitudinal specimens taken from both materials were reasonably consistent throughout the slabs.

### Fatigue Tests

Combined direct stress fatigue tests were carried out on 30-cwt. Haigh machines operating at 5,000 cycles per minute, alternating stresses being superimposed upon a range of mean tensile stresses. The test pieces used were as shown in Fig. 1, the diameter at the root of the notched specimens being the same as that of the ¼-in. parallel portion of the plain specimens. The theoretical stress concentration factor ($K_t$) associated with the 60-degree groove was 3·4.

Specimens were selected at random and the results exhibited some degree of scatter, particularly in the tests on plain specimens from the short transverse direction, and the estimated endurance limits quoted in Table 3 were derived from thirty-seven stress/log-endurance curves plotted through points representing minimum reliability. Figs. 4-7 present the values of mean stress plotted against the esti-

*Table 1. Chemical analysis of forged slabs in EX437 and Hiduminium RR77*

| Alloy | Percentage Composition | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cu | Zn | Mg | Si | Fe | Mn | Ni | Ti |
| EX437 | 4·24 | 0·07 | 0·69 | 0·81 | 0·28 | 0·85 | 0·03 | 0·04 |
| Hiduminium RR77 | 0·39 | 5·62 | 2·6 | 0·13 | 0·26 | 0·51 | 0·02 | 0·06 |

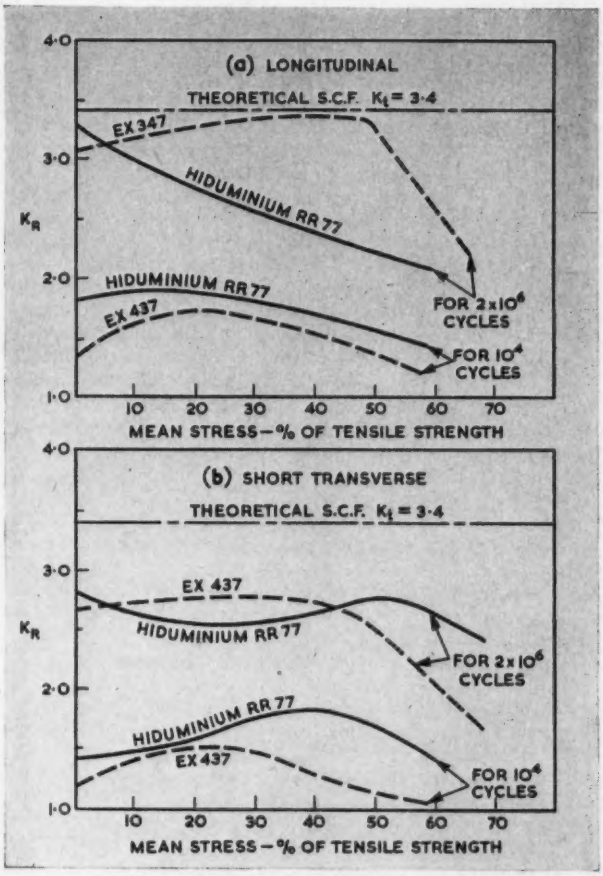


Fig. 2. Graphs showing effective strength reduction factor $K_r$ plotted against mean stress.

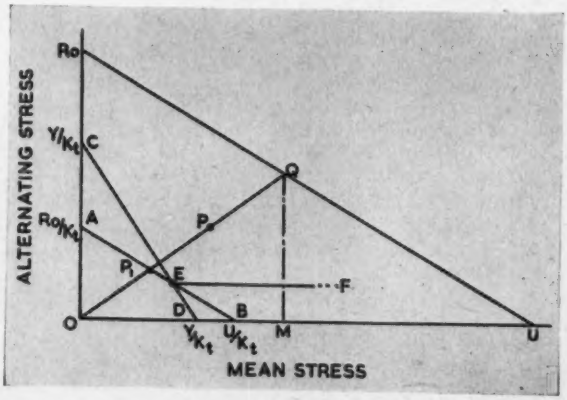


Fig. 3. Alternating stress *versus* mean stress: U = tensile strength; Y = yield stress (taken as the 0·1 per cent proof stress), and $K_t$ = theoretical stress concentration factor.

mated semi-range of alternating stress required to produce failure in $10^4$ and $2 \times 10^6$ cycles. The theoretical construction suggested by Gunn[1] has been included in these diagrams for the purpose of comparison with the experimental results. This construction is described briefly in the Appendix.

### Discussion of Results

Consideration of the results given in Table 3 shows that, for plain specimens, those from the longitudinal direction possessed a greater fatigue strength than the short transverse test pieces. This directional effect has been accentuated by assessing endurance limits from curves constructed through minimum points, the width of the scatter band for transverse specimens being greater than that for those from the longitudinal direction. An extensive examination of the micro-structure and fractured surfaces of plain specimens indicated that the scatter which was observed in the longitudinal tests was related to the direction of grain flow and the degree of working which the material had received during forging. Specimens with very narrow elongated grains making an angle with the specimen axis tended to have the shortest lives. These factors, however, did not completely explain the scatter in the short transverse specimens.

Regarding notched test pieces, there was not such a marked difference between the endurance limits for longitudinal and short transverse directions as that exhibited by the results for plain test pieces, this being attributable to the fact that the degree of scatter was considerably less where stress concentrations had been superimposed. In the case of Hiduminium RR77, the estimated endurance limits for notched specimens at $2 \times 10^6$ cycles, given in Table 3, were approximately 30 per cent of the values for $10^4$ cycles, whereas for EX437 the estimated failing stress for the higher endurance was about 25 per cent of that for $10^4$ cycles. Consideration of the results for the plain test pieces of both alloys indicates that the endurance limit for $2 \times 10^6$ cycles was nearly 60 per cent of the value for $10^4$ cycles.

It is apparent from these observations that the effect of the stress raiser is greater at the higher level of endurance. This fact is evident also from the curves for notched specimens in Figs. 4 and 5, in which the alternating stresses to produce failure in $10^4$ cycles were appreciably higher than those predicted by theoretical considerations, whereas in Figs. 6 and 7 the experimental results approach more closely the general level and shape of the calculated curve. It is considered that these results confirm the widely accepted theory that, under the comparatively high stresses which would be required in order to cause failure of notched specimens in $10^4$ cycles, the yield point of the material would be exceeded at the root of the notch, causing a redistribution of stress with a consequent reduction in effective stress concentration.

Estimation of Strength Reduction Factor ($K_r$)—A method of determining the value of effective strength reduction factors associated with the series of fatigue tests on notched specimens is explained briefly in the Appendix. Table 4 has been compiled in this way from Figs. 4-7, and gives values of $K_r$ for both alloys for increments in mean stress of 2·5 t.s.i. The variation in the effective strength reduction factor is shown in Fig. 6, where values of $K_r$ are plotted against mean stress expressed as a percentage of the tensile strength.

It may be seen that in no case did the value of the effective strength reduction factor $K_r$ exceed 3·4 (the theoretical value calculated according to Neuber), the values for an endurance of $10^4$ cycles being appreciably lower than those determined for the fatigue tests of longer duration. The results show that the value of $K_r$ for any one test condition did not remain constant, even up to the mean stress corresponding to the commencement of local yielding, except in the case of EX437 tested up to $2 \times 10^6$ cycles. In this series of tests, the experimental points in Fig. 7 were in closer agreement with the theoretical construction for the longitudinal and short transverse material.

Thus, it is not recommended that the behaviour, under combined direct stress fatigue conditions, of specimens containing stress concentrations should be assessed from data on plain specimens and a knowledge of the effective strength reduction factor at zero (or any other single) mean stress.

Fig. 2 shows that the value of $K_r$ is decreased as the mean stress is increased above 40-50 per cent of the tensile strength. This level of mean stress is associated with the commencement of yielding at the root of the notch, and where this is more marked, as evidenced by the presence of a sharper "knee", the reduction of $K_r$ is also more apparent.

Notch Sensitivity—In order to assess the relative merits of the two alloys, it will be helpful to base the comparison on the performance under specified mean stresses which may be associated for design purposes with the particular endurances which have been examined in this investigation. Where the number of stress cycles to which a structural component may be subjected is low ($10^4$), a relatively high mean stress of the order of 50 per cent of the tensile strength may be considered. From Fig. 2, the EX437 was the less notch sensitive alloy at $10^4$ cycles, although neither material attained a value for $K_r$ in excess of 1·7 at a mean stress of 50 per cent of the tensile strength.

Considering an endurance of $2 \times 10^6$ cycles, mean stresses in the range 10-25 per cent of the tensile strength may be assumed for the design of structural components of both civil and military aircraft. Fig. 2 shows that under these particular conditions EX437 possessed higher values of $K_r$ than the Hiduminium RR77, for both longitudinal and short transverse material. From Fig. 7 it may be seen that the experimental points coincide with the predicted curve for notched test pieces in EX437 (longitudinal), indicating that the theoretical stress concentration factor had been fully achieved. This result is surprising, since this particular material possessed the lower 0·1 per cent proof stress/tensile strength ratio (0·75), and, according to the normally accepted theory, a redistribution of stress around the root of the notch would have been anticipated with a consequent reduction in the effective stress concentration. However, it has been stated[3] that a source of failure can be at first slowly developed, and then rapidly propagated causing sudden collapse, even though the material had been known to be ductile.

### General Discussion and Conclusions

The position of the theoretical curve depends essentially upon the slope of the line drawn through the points representing results of fatigue tests on plain specimens. Consequently, a wide range of mean stresses should be examined in order to obtain maximum accuracy. Reference to Fig. 3 shows that the height of the theoretical curve above the mean stress axis is governed by the position of the point E, which represents the commencement of local yielding at the base of the notch and which is determined by two lines intersecting at an acute angle. Figs. 5 (a) and 6 (a) demonstrate the wide variation which may occur in the position of E, which lends support to the suggestion made earlier that it would be unwise to predict the behaviour of notched specimens from theoretical considerations only.

The method of interpretation which has been applied to the results of fatigue tests, carried out under combined direct stress on plain and notched forged specimens, has enabled values to be determined for the effective strength reduction factors at specified endurances for material from the longitudinal and short transverse directions of large forged slabs in Hiduminium RR77 to DTD 5024, and an alloy EX437 conforming to the composition of BS L77, both materials having been quenched in boiling water after

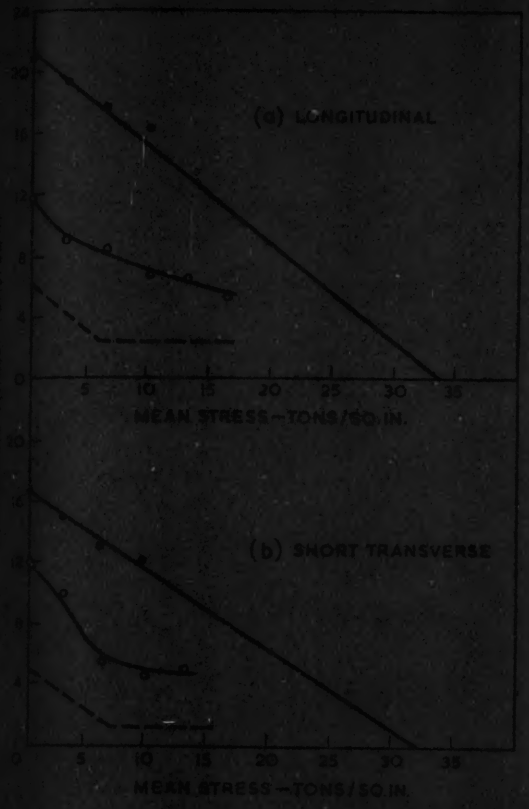


Fig. 4. Hiduminium RR77 forged slab (endurance $10^8$ cycles).

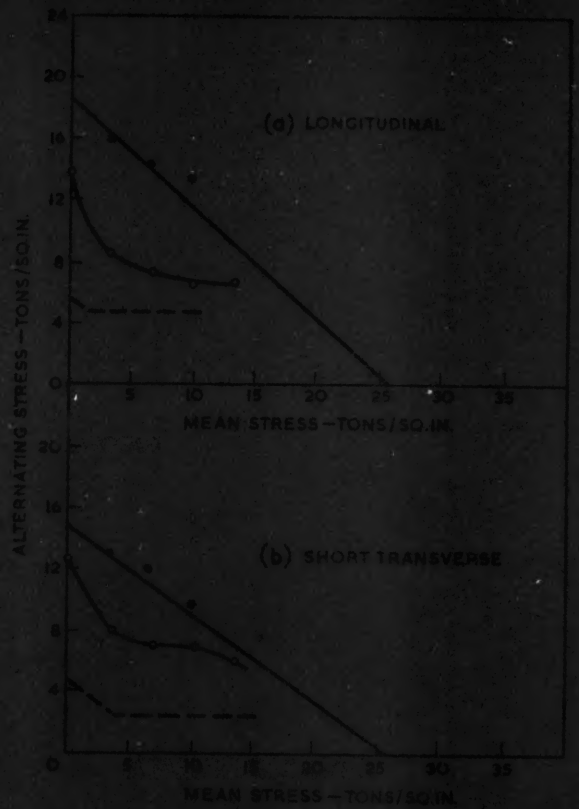


Fig. 5. EX437 forged slab (endurance $10^8$ cycles).

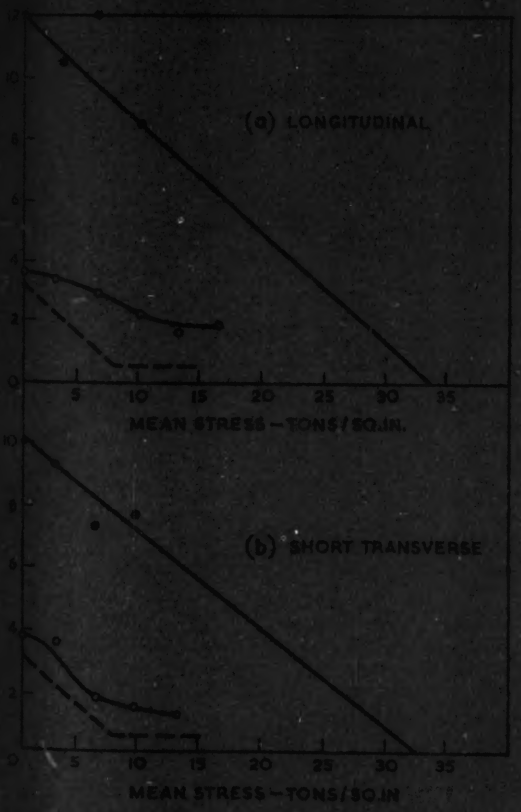


Fig. 6. Hiduminium RR77 forged slab (endurance $2 \times 10^8$ cycles).

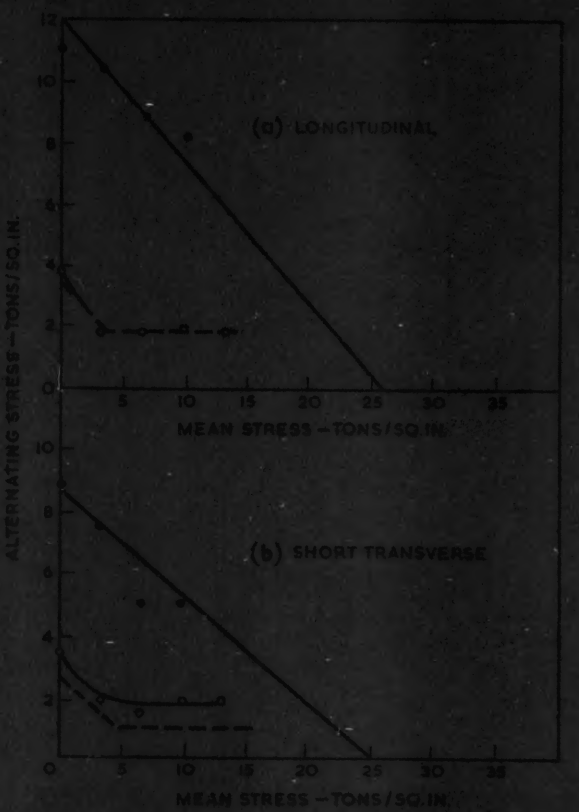


Fig. 7. EX437 forged slab (endurance $2 \times 10^8$ cycles).

(The above graphs show alternating stress plotted against mean stress for various degrees of endurance.)

*Table 2. Results of tensile tests on EX437 and Hiduminium RR77 slabs*

| Alloy | Direction | Location | 0·1% Proof stress (p.s.) (t.s.i.) | Tensile stress (t.s.) (t.s.i.) | Elong. % on $4\sqrt{A}$ | Ratio: 0·1% p.s. / t.s. |
|---|---|---|---|---|---|---|
| EX437 (composition to BS L77) | Short transverse | External | 20·0 | 25·6 | 4 | 0·78 |
| | | Internal | 18·7 | 24·6 | 4 | 0·76 |
| | Longitudinal | External | 19·1 | 25·9 | 11 | 0·74 |
| | | Internal | 18·4 | 25·5 | 11 | 0·72 |
| Hiduminium RR77 (DTD 5024) | Short transverse | External | 29·2 | 33·4 | 2 | 0·87 |
| | | Internal | 28·3 | 31·1 | 1½ | 0·91 |
| | Longitudinal | External | 29·5 | 33·6 | 10 | 0·88 |
| | | Internal | 29·6 | 33·6 | 12 | 0·88 |

*Table 3. Estimated endurance limits at $10^4$ and $2 \times 10^6$ cycles for EX437 and Hiduminium RR77 under mean tensile stress*

| Mean Tensile Stress (t.s.i.) | Endurance (cycles) | Endurance Limit (± t.s.i.) for: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hiduminium RR77 | | | | EX437 | | | |
| | | Longitudinal | | Short Transverse | | Longitudinal | | Short Transverse | |
| | | Plain | Notched | Plain | Notched | Plain | Notched | Plain | Notched |
| Zero | $10^4$ | 21·0 | 11·7 | 16·8 | 12·0 | 17·8 | 13·6 | 14·0 | 12·6 |
| | $2 \times 10^6$ | 12·0 | 3·7 | 10·1 | 3·6 | 11·1 | 3·8 | 9·0 | 3·3 |
| 3·3 | $10^4$ | 19·4 | 9·0 | 15·0 | 10·0 | 16·0 | 8·4 | 13·0 | 8·0 |
| | $2 \times 10^6$ | 10·6 | 3·4 | 9·4 | 3·4 | 10·3 | 1·8 | 7·5 | 1·9 |
| 6·6 | $10^4$ | 17·6 | 8·4 | 13·0 | 5·4 | 14·2 | 7·4 | 12·0 | 7·0 |
| | $2 \times 10^6$ | 12·0 | 2·9 | 7·2 | 1·7 | 8·8 | 1·8 | 5·0 | 1·4 |
| 9·9 | $10^4$ | 16·2 | 6·8 | 12·0 | 4·7 | 13·2 | 6·5 | 9·6 | 7·0 |
| | $2 \times 10^6$ | 8·4 | 2·2 | 7·7 | 1·4 | 8·2 | 1·9 | 5·0 | 1·8 |
| 13·2 | $10^4$ | | 6·6 | | 5·1 | | 6·6 | | 6·2 |
| | $2 \times 10^6$ | | 1·6 | | 1·2 | | 1·8 | | 1·8 |
| 16·5 | $10^4$ | | 5·4 | | | | | | |
| | $2 \times 10^6$ | | 1·9 | | | | | | |

*Table 4. Values of effective strength reduction factor $K_r$, determined from Figs. 4-7.*

| Mean Tensile Stress (t.s.i.) | EX437 | | | Hiduminium RR77 | | |
|---|---|---|---|---|---|---|
| | % of Tensile Strength | $K_r$ for endurance of: | | % of Tensile Strength | $K_r$ for endurance of: | |
| | | $10^4$ Cycles | $2 \times 10^6$ Cycles | | $10^4$ Cycles | $2 \times 10^6$ Cycles |
| | 0·1% p.s./t.s. = 0·73 | | Longitudinal Direction | | 0·1% p.s./t.s. = 0·88 | |
| 0 | 0 | 1·37 | 3·09 | 0 | 1·82 | 3·29 |
| 2·5 | 9·7 | 1·61 | 3·18 | 7·5 | 1·89 | 3·06 |
| 5·0 | 19·4 | 1·72 | 3·27 | 14·9 | 1·89 | 2·90 |
| 7·5 | 29·1 | 1·66 | 3·33 | 22·3 | 1·86 | 2·69 |
| 10·0 | 38·7 | 1·55 | 3·36 | 29·8 | 1·80 | 2·57 |
| 12·5 | 48·4 | 1·39 | 3·33 | 37·1 | 1·71 | 2·42 |
| 15·0 | 58·0 | 1·20 | 2·72 | 44·6 | 1·61 | 2·31 |
| 17·5 | 67·7 | — | 2·09 | 52·0 | 1·53 | 2·19 |
| 20·0 | 77·4 | — | 1·47 | 59·5 | 1·42 | 2·08 |
| | 0·1% p.s./t.s. = 0·77 | | Short Transverse Direction | | 0·1% p.s./t.s. = 0·89 | |
| 0 | 0 | 1·18 | 2·67 | 0 | 1·38 | 2·79 |
| 2·5 | 9·9 | 1·38 | 2·72 | 7·7 | 1·44 | 2·66 |
| 5·0 | 19·8 | 1·50 | 2·78 | 15·4 | 1·52 | 2·57 |
| 7·5 | 29·6 | 1·46 | 2·77 | 23·1 | 1·64 | 2·57 |
| 10·0 | 39·5 | 1·29 | 2·74 | 30·7 | 1·77 | 2·56 |
| 12·5 | 49·3 | 1·14 | 2·55 | 38·4 | 1·83 | 2·65 |
| 15·0 | 59·2 | 1·05 | 2·10 | 46·1 | 1·76 | 2·73 |
| 17·5 | 69·1 | — | 1·65 | 53·8 | 1·60 | 2·77 |
| 20·0 | — | — | — | 61·4 | 1·36 | 2·61 |

solution treatment. The notch sensitivity assessed by this method depended upon a number of factors; namely, the magnitude of the applied mean stress, the direction from which the specimens had been taken in the original forgings, and the endurance. The effect of the stress raiser was considerably more detrimental at the higher levels of endurance, although at $10^4$ cycles both alloys were relatively insensitive to the presence of the notch, EX437 having the lower value of strength reducion factor when the alloys were compared on a basis of mean stress expressed as a percentage of the tensile strength.

The tests indicated that EX437 was more notch sensitive in the longitudinal direction than in the short transverse at the levels of endurance investigated, and it was considered interesting to find that this alloy, with a value for the ratio 0·1 per cent proof stress/tensile strength of about 0·75, was in general more notch sensitive for an endurance of $2 \times 10^6$ cycles than Hiduminium RR77.

It is considered that the approach described may assist aircraft constructors in the assessment of materials for components operating under a combination of steady and alternating direct stresses, and which may involve stress concentrations.


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3. A. A. Golestaneh, "The Study of Fast Fracture of Centrally Notched Sheet Specimens with Particular Reference to Aluminium Alloys L72 and L73", S. & T. Memo No. 27/57, December 1957 (M.O.S.).


## Appendix

CONSTRUCTION OF THEORETICAL DIAGRAM FOR NOTCHED SPECIMENS[1]—Referring to Fig. 3, the position of Ro on the vertical axis is determined by drawing RoU through the points representing experimental results for plain specimens and the value U on the mean stress axis. In the present investigation, where only a limited number of mean stresses were applied, the best straight line has been drawn which does not necessarily pass through the experimental point for zero mean stress (see Figs. 4-7). The points A and B representing stresses of $\frac{Ro}{K_t}$ and $\frac{U}{K_t}$, respectively, are joined. The straight line CD is obtained by joining the points representing the value $\frac{Y}{K_t}$, plotted on both axes. AB and CD intersect at E, this point representing the theoretical combination of mean and alternating stresses under which local yielding at the base of the notch would commence. It is assumed that the range of alternating stress will not change until general yielding occurs, and the theoretical diagram representing failure of notched specimens is, therefore, the line AEF, where EF is parallel to the mean stress axis. It should be noted that EF will not continue parallel to the horizontal axis once general yielding has occurred, but this condition has been ignored, since the associated stresses would be of greater magnitude than the normal design values.

DETERMINATION OF STRENGTH REDUCTION FACTOR, $K_r$—Referring to Fig. 3, Q is a point representing failure in N cycles of plain specimens under mean stress M. P is the point of intersection of OQ and an experimental curve for notched specimens, also failing in N cycles.

It is suggested that the strength reduction factor $K_r$ be defined as the ratio $\frac{OQ}{OP}$. If P lies on the theoretical line AE at $P_1$, then

$$K_r = \frac{OQ}{OP} = \frac{ORo}{OA}$$

But ORo represents a stress of Ro, and OA represents a stress of $\frac{Ro}{K_t}$

$$\therefore \frac{ORo}{OA} = K_t$$

That is, when the experimental points for notched specimens lie on the theoretical curve (Fig. 7 (a), $K_r = K_t$ and the theoretical stress concentration factor is fully effective.

This method of assessment attempts to take into account the effect of the superimposed mean stress acting at the root of the notch. If ratios be calculated on vertical lines such as QM, values of $K_r$ considerably in excess of the theoretical factor $K_t$ can be obtained, being a maximum where the vertical line passes through E.


The authors wish to thank the directors of High Duty Alloys Ltd. for permission to publish this article.

# PROBLEMS IN DESIGN

**Problem No. 8 (June), set by R. E. W. Baker: Input shaft to drive output shaft in the same direction and at the same speed as its own. Output also to reciprocate radially in a straight path at one complete reciprocation per revolution of shafts.**

When it was decided to set the above problem, a number of alternative types of solution appeared likely. It came as an agreeable surprise to find that not only were many variants on these expected solutions submitted, but also several unusual ones that were not anticipated. On this occasion several poorly drawn entries have been included on account of their ingenuity. We feel that if these were engineered properly they would be practicable propositions.

Among those solutions employing cranks and sliding pairs, we consider **H. R. Holliday's** solution (Fig. 1) to be very simple and effective. It is self-explanatory, and, considered as the basis for a machine requiring a motion of this sort (for running at fairly slow speeds), it is admirable. The same idea was also submitted by J. A. W. Brown, who duplicated the cranks and connecting rods, etc. An important feature is that the angular velocity of the output shaft is constant, while its lateral reciprocation is simple harmonic motion.

Another solution along comparable lines came from **J. L. P. Macnair** (Fig. 8), who also used a crank and slider but connected his shafts by gears. The gear at the end of the crank is fixed and drives the output shaft gear via an idler gear.

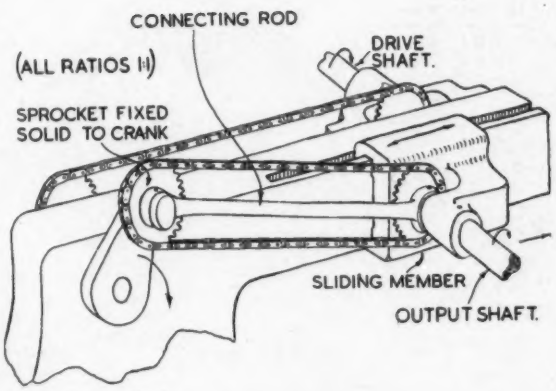



Fig. 1

When it is required to convert rotary to linear motion, the Scotch yoke is an obvious suggestion, and from among a number of entries employing this principle we singled out that of **R. A. Hammersley** (Fig. 6). Although this entry is ingenious, particularly the unconstrained scissor-like pair of chain drives (a feature just missed by two other entries), it has certain shortcomings. The arcuate scissor-like motion of the chain drives would give rise to a phase lag in the rotation of the output shaft at certain points along its lateral reciprocation.

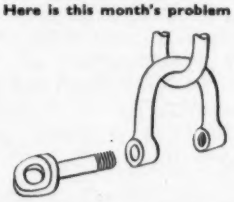
Somewhat similar in conception, but employing a gear-driven adjustable throw crank to effect lateral reciprocation, is the entry from **J. Feuillade** (Fig. 3).

The entries that follow depend, for the conversion of rotary to linear motion, upon principles which do not employ sliding pairs. When a spur pinion of half the diameter of an internal gear, which it engages, rotates around the axis of the larger gear, any point on its pitch circle will describe a straight line through the centre of the larger gear. This principle formed the basis of a number of excellent entries, most of which were admirably drawn. The differences concerned only the method of reversing the direction of rotation of the input shaft, a double reversal being necessary to meet the requirements of the problem.

**J. Tindale** (Fig. 5), for compactness, chose to duplicate the hypocloidal gear and then interpose a 1:2 spur gear. This seemed to us rather an elaborate way to go about it. **D. C. Wood** (Fig. 4), G. Humphreys, V. J. G. Harding, of Sydney, Australia, and several others employed a bevel reversing gear on the input side, while **H. T. E. Hone** (Fig. 7) chose a chain drive to rotate the planet carrier anti-clockwise and so reverse rotation of the output shaft. Gear-driven mechanisms of the above kinds can be developed for high-speed duty, and when properly balanced can be nearly vibrationless.

**PROBLEMS IN DESIGN**

**Here is this month's problem**



Some apparently clumsy devices have, despite many attempts to improve them, retained the favour of either manufacturer or user. Such a device is the common shackle for joining chains. This month's problem is to suggest a new design that will: (a) perform all the functions of the traditional design; (b) have no loose parts; (c) have no springs or delicate pivot pins to go wrong; (d) be capable of withstanding the arduous conditions of wear and corrosion encountered on ships, etc., and (e) be as cheap to manufacture as the present design.

(Readers submitting entries which appear to be original and to satisfy the above conditions will be notified in advance, in order that they can make application for Provisional Patent protection, before publication of their ideas in this Journal.)

*Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12×12 in., please!), to the Editor, "Problems in Design No. 11 (September)". Closing date October 15.*

# designer's notebook

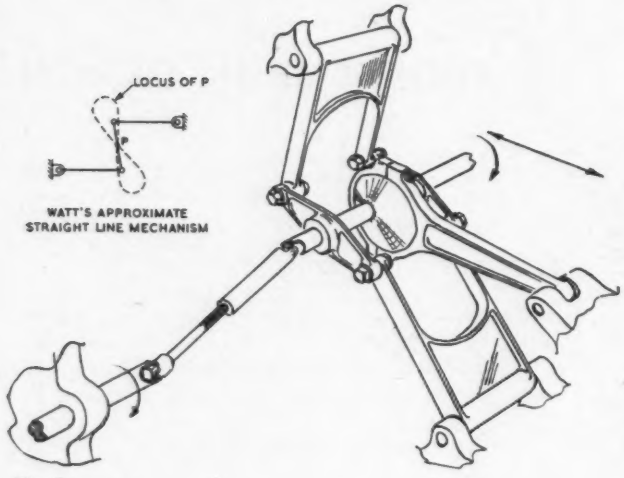



Fig. 2

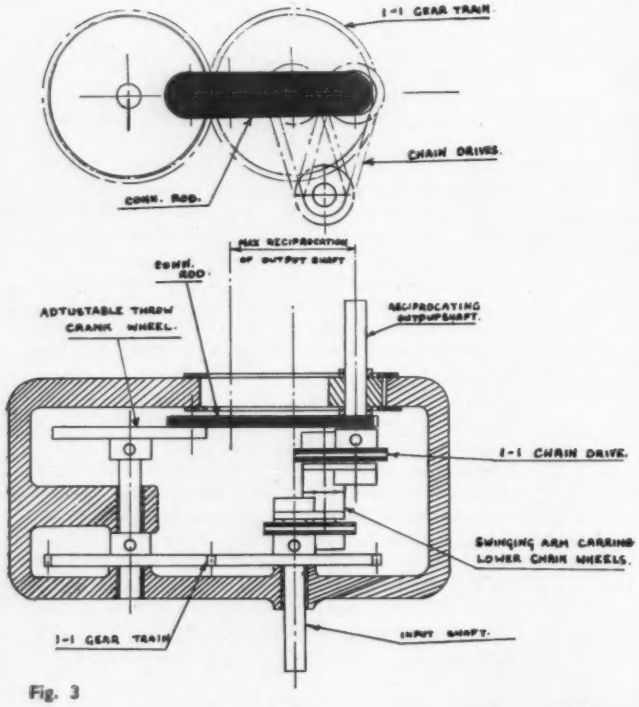



Fig. 3

The remaining two entries struck us as being very simple and novel, and effective for certain types of duty. **P. Murdoch** (Fig. 9) employs two cranks, A and B. Crank B carries at its outer end a freely rotatable shaft on which a sprocket (C) is fixed. This sprocket is driven by a chain from sprocket D, which is attached to the fixed housing carrying the output shaft bearings. Sprocket D has twice as many teeth as sprocket C. The output shaft F is carried in bearings at the other end of crank E. The two cranks B and E are of equal length.

When A is rotated through an angle $\theta$, sprocket C rotates through $-2\theta$ relative to crank B, and is thus inclined $-\theta$ to the vertical. Thus the output shaft F moves in a straight line perpendicular to the plane of the paper and has simple harmonic motion of an amplitude (single) equal to twice the crank radius, going through one complete cycle for each revolution of A. Drive to the output shaft is by a sprocket G, fixed to crank B which drives by means of a chain sprocket H fixed to the output shaft. The output shaft is thus driven in the same direction and at the same speed as the input. The simple construction of the mechanism, which uses two nearly identical cranks, standard sprockets and chains, makes it an attractive proposition for a lightly loaded mechanism for low speeds where a large amplitude of reciprocation is required. Adjustable length cranks could be fitted to provide considerable alteration to the amplitude of reciprocation.

The final entry, from **J. Bottrill** (Fig. 2) employs Watt's Straight Line Motion to produce the lateral reciprocation. No gears are employed, reciprocation being produced by an eccentric fixed to the output shaft. Flexing and axial movements of the input shaft are catered for by means of two universal joints and a spline coupling, as in motor car transmission. Although the Watt's Straight Line Motion can only be used for certain amplitudes of reciprocation, beyond which it ceases to be rectilinear, in this case it would appear to offer a very simple solution.

Once again we have found it extremely difficult to choose between some of the entries, and we are encouraged by our readers' efforts to try to present their entries rather better than in the past.

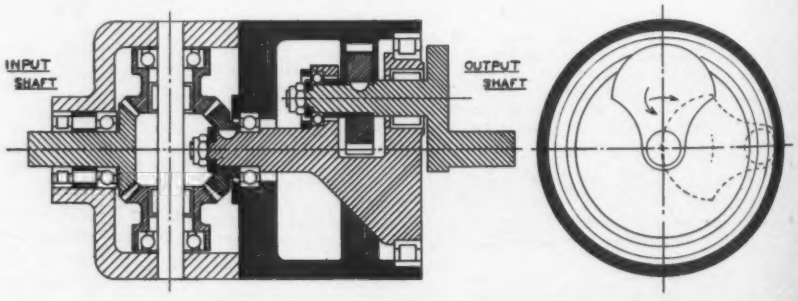



Fig. 4

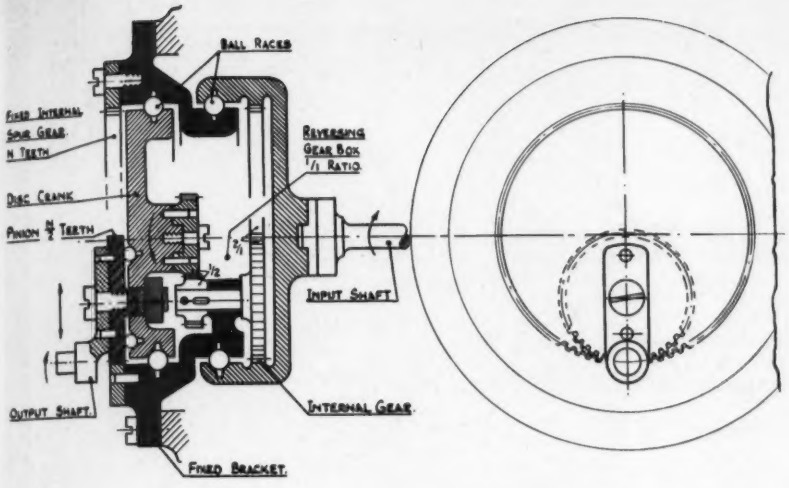



Fig. 5

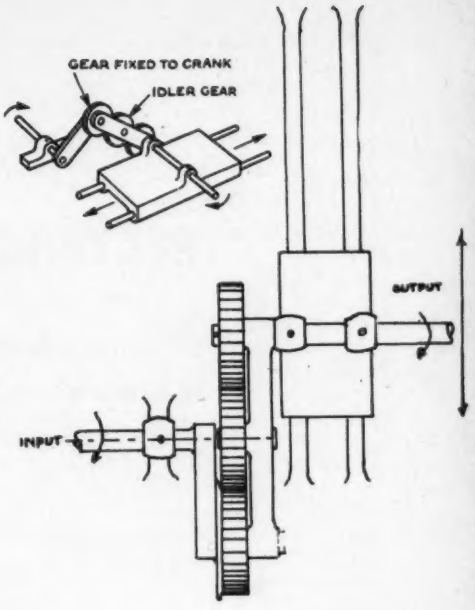



Fig. 8

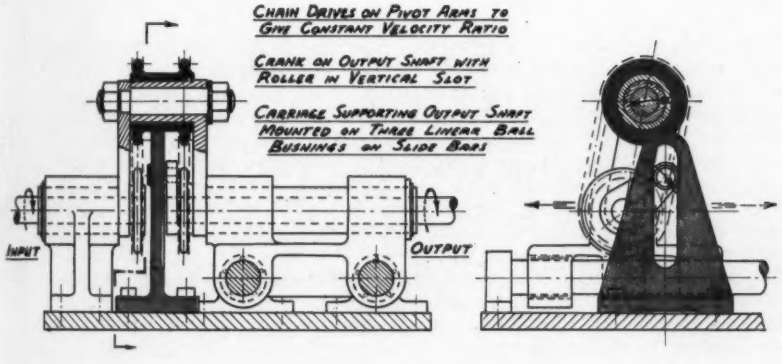

CHAIN DRIVES ON PIVOT ARMS TO GIVE CONSTANT VELOCITY RATIO
CRANK ON OUTPUT SHAFT WITH ROLLER IN VERTICAL SLOT
CARRIAGE SUPPORTING OUTPUT SHAFT MOUNTED ON THREE LINEAR BALL BUSHINGS ON SLIDE BARS
INPUT
OUTPUT

Fig. 6

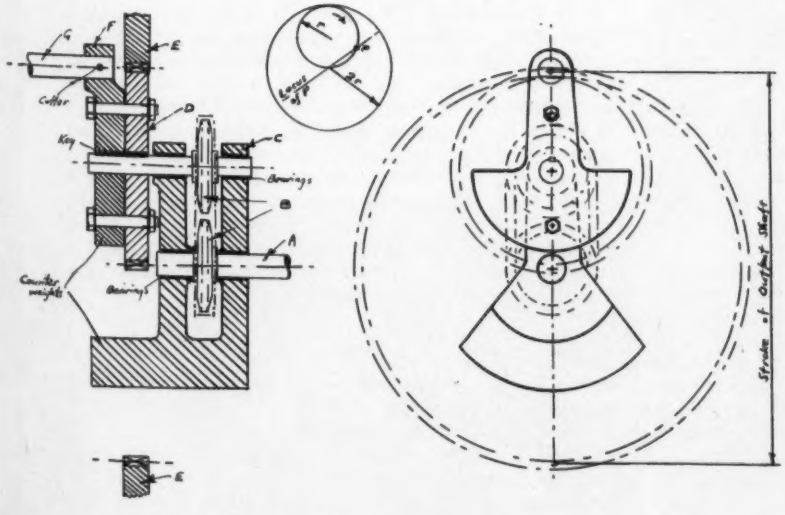



Fig. 7

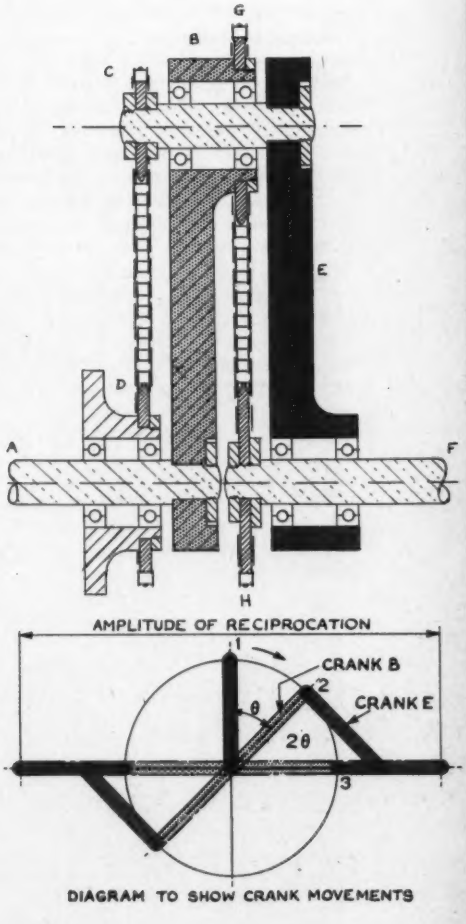



Fig. 9

# RECTANGULAR HOLLOW SECTIONS

*This article indicates relevant factors influencing the design of structures using rectangular hollow sections. Examples of several applications incorporating these tubes are given*

WITHIN the last decade extremely rapid progress has been made in the use of circular tubes in structural and mechanical engineering, but obviously they should not be used without justification. They are highly efficient when subjected to torsion, compression or tension, but are inefficient as beams unless the loads are applied in a number of different planes, when, of course, they offer the same resistance in all directions. As the use of tubes for structural and mechanical purposes increases, it is inevitable that new tubular shapes be required. Rectangular hollow sections (R.H.S.) are meant to be complementary to tubes, not to replace them. Nevertheless, there are many fabrication shops accustomed to conventional constructional steelwork where, without introducing new plant, it would be possible to employ R.H.S.

Although there is no more difficulty in welding a cleat or a baseplate to a tube than to a rolled section, there are many occasions when the flat surfaces presented by R.H.S. are of considerable value. The ends can be sawn or flame cut, straight or mitred, and the joints welded in the normal way.

Square or rectangular hollow sections as manufactured by Stewarts & Lloyds Ltd. are shown in Fig. 3. These are produced by passing newly-manufacured or reheated tubes through a series of rolls, which change them from a circular section to the shape required. They are made in two ranges produced from continuous weld and seamless tubes. Although there is a reasonable choice of sections in the continuous weld range, they are limited in size to 3¼ in. square or 5 by 2½ in. because the maximum size of tube produced by this process is 4½ in. outside diameter.

A rather smaller range of seamless R.H.S. is available at the present time, but the range is being constantly extended. R.H.S. 5 in. square or 6 by 4 in. are readily available, while sections 7½ in. square have been rolled experimentally. The continuous weld tubes are made from grade 16 open-hearth steel of a guaranteed minimum yield stress of 16 t.s.i. The seamless R.H.S. are also made in grade 20 open-hearth steel (guaranteed yield stress 20 t.s.i.) Both conform to the physical properties required by BS 1775:1951 ("Steel tubes for mechanical, structural and general engineering purposes").

When R.H.S. were made available about two years ago they immediately found favour in the mechanical handling field. Applications vary from the ubiquitous pallet, examples of which are shown in Fig. 2, to the all-British tower crane shown in Fig. 4, the main chords of which are of R.H.S., and the bracings of tubes. R.H.S. are being used extensivelv for agricultural equipment and earth-moving machinery, such as harvesters, trailers, bulldozers, cattle pens, grain-driers and gates. In other mechanical engineering fields, R.H.S. are replacing members formerly made by welding rolled steel channels or angles toe-to-toe. A simple application is shown in Fig. 5. R.H.S. have also been used in a range of balustrading designs for sea fronts and the parapets of bridges. It is probable, however, that the greatest sphere of application, still largely untapped, is for structural purposes.

### Design Procedure

At this point it is relevant to consider methods of design which may be employed with R.H.S. At the present time R.H.S. are officially recognised, together with circular tubes and conventional rolled sections, by BS 449:1959 ("The use of structural steel in building"). In the absence of any standard for machinery, the provisions of BS 449 may reasonably be applied to other frameworks not subjected to heavy dynamic forces. It is of interest to quote the requirements for the minimum thickness of metal laid down in clause 12 of this Specification. These are that, unless special protection against corrosion is provided (such as galvanising), sealed hollow sections used for external construction shall be not thinner than 8 s.w.g. (0·160 in.), and for construction not so exposed not thinner than 10 s.w.g. (0·128 in.). There is also a provision to avoid the possibility of local buckling. It is stated that the thickness of material in inches shall be not less than:

$$t = \frac{1}{10}\sqrt[3]{D}$$

where D = the diagonal dimension taken to the outside of the section, in inches.

GEOMETRICAL PROPERTIES—Continuous weld R.H.S. are rolled with rounded corners, the internal and external radii being once and twice the wall thickness respectively. The manufacturers have borne this fact in mind when calculating the geometrical properties of the section. The larger R.H.S. usually have corners which are much more square,

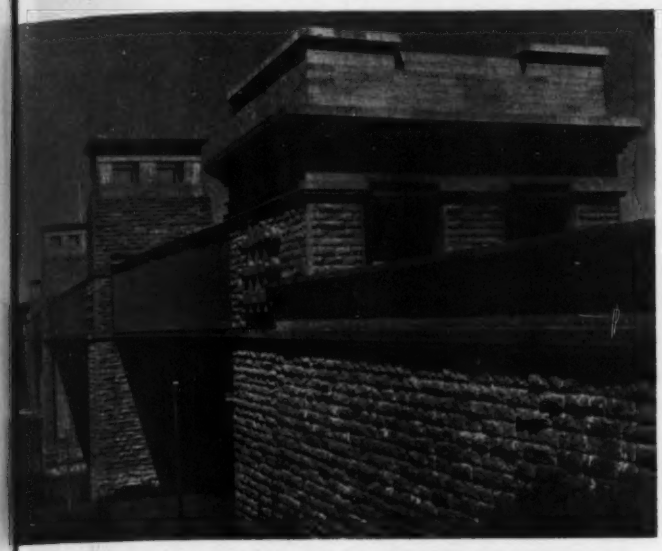


Fig. 1. An early application of the principle of R.H.S. used in the construction of the Britannia bridge.

with a small chamfer on the outside. In any case, little error would be involved if the rounding were ignored. This can be shown by calculating the moment of inertia of a 6 by 4 by $\frac{1}{4}$ in. R.H.S. about its XX axis, using the simple formula:

$$I_{xx} = \frac{BD^3 - bd^3}{12}$$

where B and D = the outside dimensions, and
b and d = the inside dimensions.

$$\text{Then } I_{xx} = \frac{(4\times6^3) - (3{\cdot}5\times5{\cdot}5^3)}{12}$$

$$= 23{\cdot}47 \text{ in.}^4$$

In a similar manner the approximate value of the section modulus could be obtained from the formula:

$$Z_{xx} = \frac{BD^3 - bd^3}{6D}$$

The value of the radius of gyration "r" may also be derived from the formula:

$$r = \sqrt{I/A}$$

("k" also is sometimes used to denote radius of gyration) where A = the cross-sectional area.

It is not the object of this article to teach the theory of structures. The methods of calculating bending moments and shear forces, together with appropriate formulæ, are to be found in the appropriate books, such as *The Steel Designers' Manual.** It is important, however, to describe the structural behaviour of R.H.S. under various types of loading, and to demonstrate how the various members are designed in accordance with BS 449.

FLEXURE—The most suitable R.H.S. for use as beams are those which have a high depth/breadth ratio, such as 5 by $2\frac{1}{2}$ in. Table 2 of BS 449:1959 states that the allowable stresses $p_{bo}$ or $p_{bt}$ in bending for grade 16 and 20 R.H.S. shall be 10·5 and 13·0 t.s.i. respectively. Suppose that it is required to design a beam with fixed-ends to carry a uniformly distributed load of 5 tons over a span of 7 ft. Then, the maximum bending moment at the ends of the beam:

$$M = -\frac{WL}{12} = -\frac{5\times7\times12}{12}$$

$$= -35 \text{ tons in.}$$

If grade 16 steel is chosen, then the section modulus required:

$$Z = M/f_{bo} = M/f_{bt}$$

$$= 35/10{\cdot}5 = 3{\cdot}33 \text{ in.}^3$$

As the value of $Z_{xx}$ of a 5 by $2\frac{1}{2}$ by $\frac{3}{16}$ in. section is 3·37 in.$^3$, this section would be suitable.

DEFLECTION—In normal constructional steelwork the maximum deflection of any beam shall not exceed 1/325

* Published by Crosby Lockwood.

Fig. 2. Application of R.H.S. to pallets and crates (Tubewrights Ltd.).

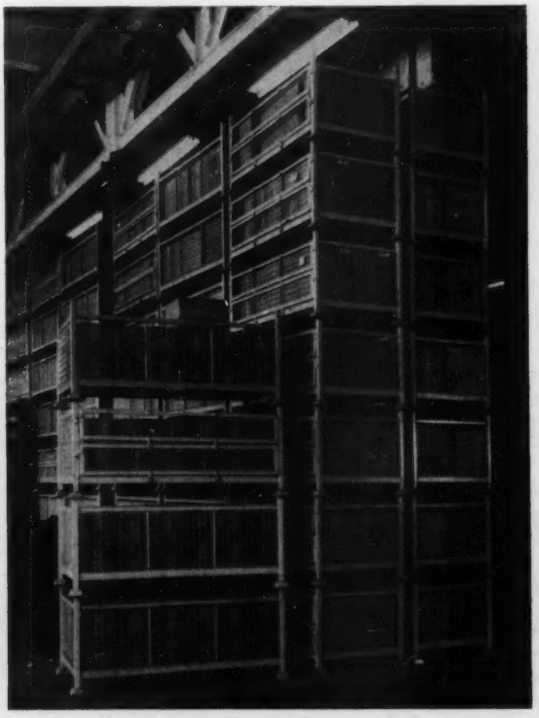
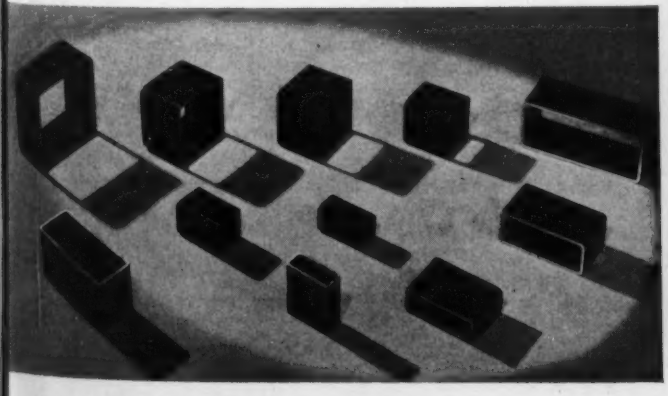


Fig. 3. (*below*) Various rectangular hollow sections.



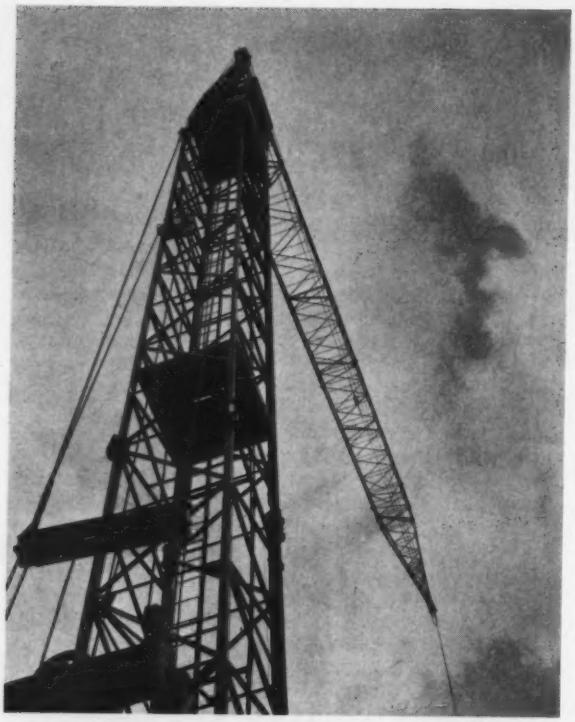


Fig. 4. Buildmaster tower crane with main members of rectangular hollow sections (Ruston-Bucyrus Ltd.).

Fig. 5. Portable hydraulic platform by Thomas Adshead & Sons.

span. However, where greater deflection would not impair the strength and efficiency of the structure, lead to damage of finishings, or be unsightly, it is permissible to exceed this limit. Deflection is very considerably reduced when the ends of a beam are fixed in position as in the example just calculated.

TENSION—As triangulated and other frameworks can be so arranged that all the tension members are axially aligned, the resulting stress is uniformly distributed over the whole section, the members thus being used with maximum efficiency. By contrast, however, many angles and tees are connected eccentrically, in which case parts of the outstanding legs must be ignored in stress calculations, as stipulated in clause 42 of BS 449: 1959. The allowable stresses in tension $p_t$ in Table 19 in BS 449: 1959 are 9·5 and 12·0 t.s.i. respectively for grade 16 and 20 R.H.S.

COMPRESSION—The load-carrying capacity of a strut or column depends on a property known as the slenderness ratio. Short stout struts, with a low slenderness ratio, collapse through the crushing of the material. Long slender struts, with a high slenderness ratio, collapse much more readily because they buckle into a bow shape within their length. Struts of medium length collapse through some combination of the two extreme modes of failure.

Slenderness ratio is defined as $l/r$, where $l$ = effective length of the strut, and r = radius of gyration of the section. The value of $l$ depends on the amount of restraint which is applied at the ends of the strut. Clause 31(a) of BS 449: 1959 expresses the effective length $l$ as a ratio of the actual length L, from centre-to-centre of intersections with supporting members, as follows:

*TABLE 1*

| | Case | $l$ |
|---|---|---|
| (i) | Effectively held in position and restrained in direction at both ends. | 0·7 L |
| (ii) | Effectively held in position at both ends and restrained in direction at one end. | 0·85 L |
| (iii) | Effectively held in position at both ends, but not restrained in direction. | L |
| (iv) | Effectively held in position and restrained in direction at one end, and at the other partially restrained in direction but not held in position. | 1·5 L |
| (v) | Effectively held in position and restrained in direction at one end, but not held in position or restrained in direction at the other end. | 2·0 L |

The allowable stresses $p_c$ (in t.s.i.) for axial compression in grade 16 and 20 R.H.S. are given in Table 17 of BS 449: 1959, as follows:

*TABLE 2*

| | $p_c$ | | | $p_c$ | |
|---|---|---|---|---|---|
| $l/r$ | Grade 16 | Grade 20 | $l/r$ | Grade 16 | Grade 20 |
| 0 | 9·50 | 12·00 | 140 | 2·61 | 2·75 |
| 10 | 8·98 | 11·27 | 150 | 2·33 | 2·44 |
| 20 | 8·45 | 10·54 | 160 | 2·08 | 2·17 |
| 30 | 7·93 | 9·81 | 170 | 1·87 | 1·95 |
| 40 | 7·40 | 9·08 | 180 | 1·69 | 1·75 |
| 50 | 6·88 | 8·35 | 190 | 1·54 | 1·59 |
| 60 | 6·35 | 7·62 | 200 | 1·40 | 1·44 |
| 70 | 5·83 | 6·89 | 210 | 1·28 | 1·32 |
| 80 | 5·30 | 6·16 | 220 | 1·17 | 1·21 |
| 90 | 4·77 | 5·40 | 230 | 1·08 | 1·11 |
| 100 | 4·24 | 4·70 | 240 | 1·00 | 1·02 |
| 110 | 3·75 | 4·09 | 250 | 0·93 | 0·95 |
| 120 | 3·32 | 3·56 | 300 | 0·66 | 0·67 |
| 130 | 2·94 | 3·12 | 350 | 0·49 | 0·50 |

Intermediate values may be obtained by linear interpolation.

As an example, the carrying capacity of a grade 20, 5 in. square by $\frac{1}{4}$ in. thick section, "effectively held in position and restrained in direction at both ends" over an actual height of 10 ft., will be calculated.

Now $l$ = 0·7 L (from case (i), Table 1)
= 7 ft. = 84 in.

From the manufacturers' tables, the radius of gyration
r = 1·89 in.

Therefore $l/r$ = 84/1·89
= 45

Interpolating from Table 17 of BS 449: 1959 (Table 2 above)
$p_c$ = 8·71 t.s.i.

The cross-sectional area = 6·87 sq. in.

Therefore, the allowable axial load on the section
= 6·87 × 8·71
= 59·8 tons.

TORSION—Although hollow sections display vastly

superior torsional strength to all forms of open section, such as R.S.J.s, channels and angles, the individual members of structures are much less likely to be subjected to torsion than those of machines. Nevertheless, this characteristic must contribute a great deal indirectly to the rigidity of a structure.

Considering Fig 6, the angle of twist in radians per unit length of member is:

$$\theta = \frac{Tt(b+d)}{2Gb^2d^2t^2}$$

where T = applied torque; t = thickness of the section; b = mean breadth; d = mean depth; and G = modulus of rigidity = 5,000 t.s.i.

If the length of member is L, then the total angle of twist = $L\theta$ (radians).

The average shear stress around the section may be derived from the formula $q = T/2tbd$.

An angular external corner does not influence the shear stresses, but if the internal corner is sharp then there is a local increase in stress. It has been shown that, for an internal radius equal to the thickness t, the shear stress at the corner is 1·35 times the average stress. When the internal radii are half or twice the thickness, the corresponding factors are 1·72 and 1·14 respectively.

SHEAR—In the absence of precise guidance, the allowable shear stresses for R.H.S. may be derived from *either* Table 10 or 11 in BS 449:1959. In Table 10 it is stated that the maximum shear stress $p_q$ must not exceed 7 t.s.i. for grade 16 sections and 8·5 t.s.i. for grade 20 sections. The maximum shear stress which occurs at the XX axis for a vertical load, as shown in Fig 7 (a) is derived from the formula:

$$f_q = \frac{VQ}{It},$$

where V = the shear force;
Q = the statical moment about the neutral axis of the area between the free edge and the plane through the point under consideration;
I = the moment of inertia of the *whole* section, and
t = the thickness of material.

In a hollow section there is no "free edge", but the appropriate calculations may be made by assuming that the section comprises two channels butted together along the YY axis. Consequently, as shown in Fig. 7 (a) there is no shear stress at this axis.

In Table 11 of BS 449:1959 the allowable average shear stresses $p'_q$ are quoted for the webs of rolled sections and plate girders. The appropriate average stresses for mild and high-tensile steel channels are 6·0 and 8·0 t.s.i. respectively, values which could well be applied to R.H.S. The average shear stress in the webs of R.H.S. may be derived, as shown in Fig. 7 (b), from the formula:

$$f'_q = \frac{V}{2Dt},$$

where D = the full depth of the web. This method, which is more easy to apply, is quite acceptable.

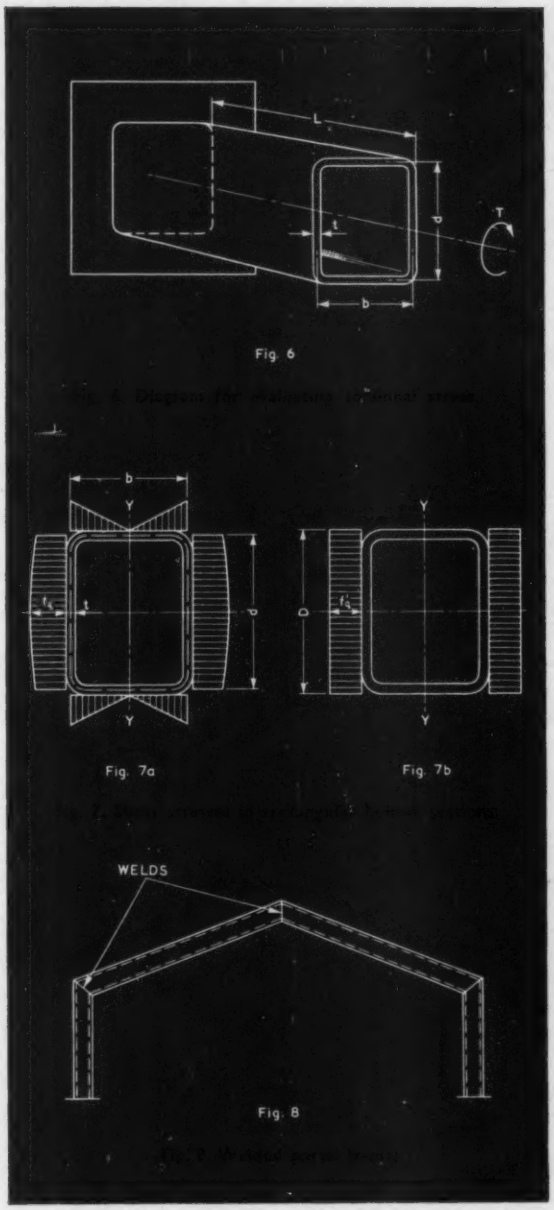
As rectangular hollow sections have two webs, they are not likely to be subjected to high shear stresses. This is of great advantage at changes of direction of members, such as the joints in the portal frame shown in Fig. 8. As no British Standard beam, with its single web, is strong enough to absorb the heavy shear forces across the knees and, sometimes, the ridge of such frames, it is always necessary to provide a diagonal plate or to insert a haunch in the re-entrant angle, or to use both devices. It has been shown by tests on similar joints in R.H.S. that such reinforcement is not required for these sections.

COMBINED STRESSES—The method of treatment of members subjected to combined stresses is given in clause 14 of BS 449:1959, which should be consulted. For example, when a beam is subjected to axial compression (or a strut is subjected to flexure) one must check that:

$$\frac{f_c}{p_c} + \frac{f_{bc}}{p_{bc}} \text{ does not exceed unity,}$$

where $f_c$ = the calculated average axial compressive stress;
$p_c$ = the allowable compressive stress in axially loaded struts (see Table 17, BS 449:1959);
$f_{bc}$ = the resultant compressive stresses due to bending about both rectangular axes, and
$p_{bc}$ = the appropriate allowable compressive stress for members subject to bending.

The formula for a beam with axial tension is similar. The remaining formulæ in clause 14 relate to equivalent stresses $f_e$. It may be stated quite categorically that it is very rare for such a combination of stresses to arise as to make the equivalent stress critical in design.




Acknowledgment is made to Stewarts & Lloyds Ltd. for information given in this article.

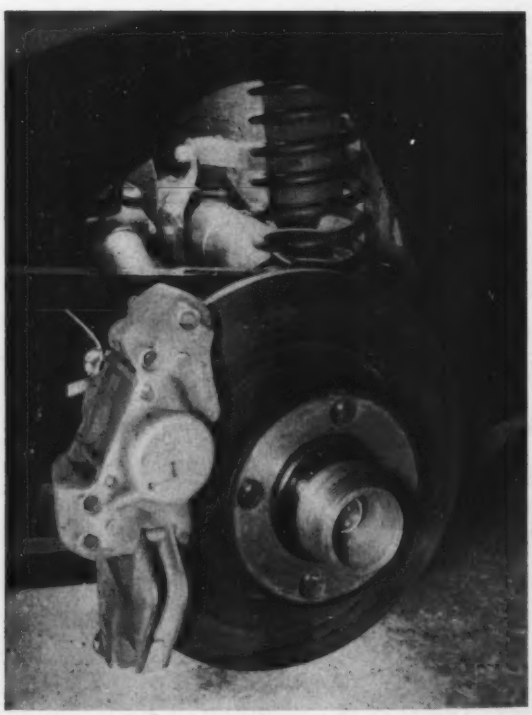
The new Gordon sports saloon.

# DESIGN HIGHLIGHTS IN NEW SPORTS SALOON

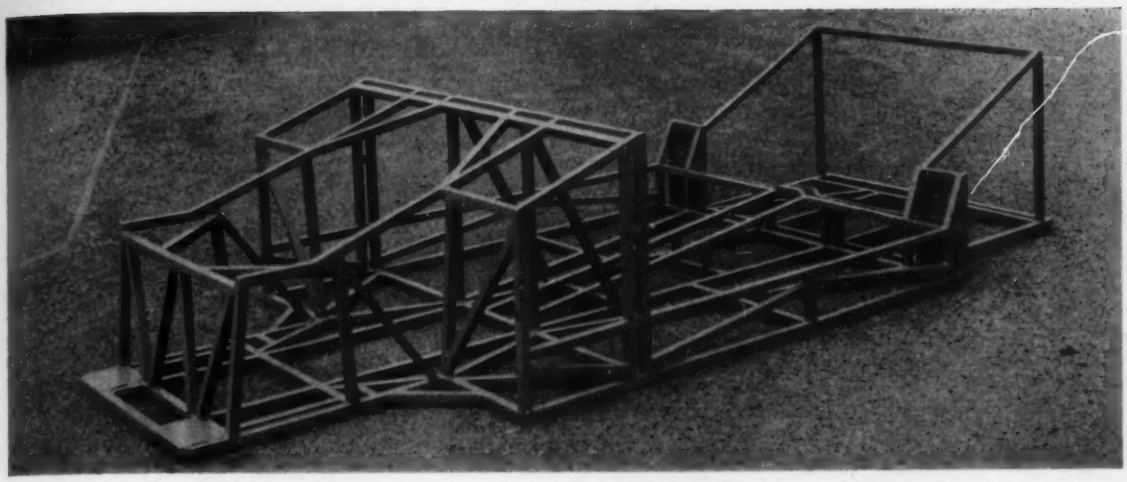
THE prototype Gordon sports saloon, designed and manufactured by the Gordon Automobile Co. Ltd., is shortly to leave for an American demonstration tour. As shown by the heading photograph, this car reflects the latest Italian styling in its Bertoné body lines. In addition, there are many interesting new features in the detailed design of the vehicle which differ from conventional practice. It has been built specifically to meet a demand in the American market for a high-performance Gran Turismo (G.T.) car, and is so designed that it will be possible for American buyers to have fitted, by East and West coast distributors, the engine and gearbox of their choice.

The prototype car is powered by a General Motors Corvette engine, which is capable of giving the car a virile performance with outstanding acceleration, and has been limited to a maximum speed of 150 m.p.h. Petrol consumption, taking into consideration the performance, is better than one might have expected, averaging between 19 and 20 miles to the gallon under all conditions. All four wheels have hydraulically operated Girling disc brakes, the system for the front wheels being independent of that for the rear wheels, but mechanically linked to it. The twin head-lamp sets are the forerunners of a new sealed-beam configuration by Lucas.

By far the most interesting design feature of this car is the space frame type of chassis construction. Although similar in some respects to certain racing cars, the frame is built entirely from 16 s.w.g. square-section mild steel tubes (known as Cold Rolled Electrical Welded (CREW) tubes). In the construction of the chassis the individual members have been electrically arc welded to form an extremely rigid yet light frame, capable of resisting road shocks and imposed loads without transmitting these to the body. The success of this design is evidenced by the excellent condition of the bodywork after a gruelling 2,000-mile run under adverse continental conditions, no sign of distortion being found at any point.



Showing part of the transverse location struts for the De Dion rear axle. Also shown is the main coil spring and subsidiary corrugated rubber spring. Note the four locating holes in the wheel hub for driving and braking.



Welded tubular chassis.

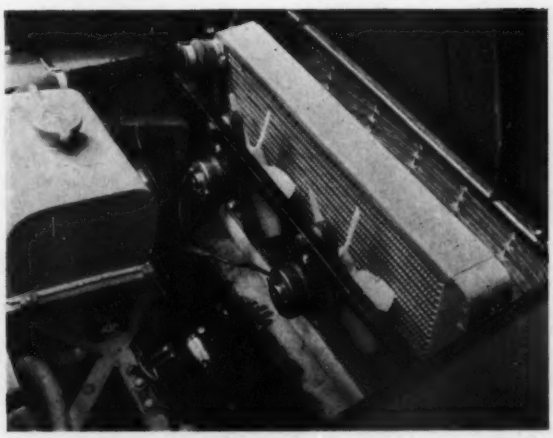
To obviate the possibility of expensive repairs in the event of damage, the main part of the chassis is set well in from the body sides, and the front so arranged that any head-on impact will be absorbed by the collapse of a subsidiary framework.

Of further interest are the parallel swinging links locating the De Dion type rear axle in a fore-and-aft direction. These links are made from 12 s.w.g. square-section tubes, the pivot points being rubber bushed for silence and ease of maintenance, and the attachments to the car being adjustable in order to maintain the precise wheelbase dimensions. The coil springs employed for the rear suspension are designed for a load condition corresponding to two passengers. When the car is fully loaded, however, a secondary corrugated hollow rubber spring comes into operation, thus giving corrected characteristics to suit the increased load. The front suspension is by wishbone links, with similar arrangement of springs. The king pin in the stub axle assembly has been replaced by ball fittings, which give improved steering characteristics. The Rudge-type knock-off wheels have been modified so that the torque is transmitted by four studs fitted to the inside face of the wheel, instead of by the conventional splines.

Another innovation is the use of two cooling fans placed immediately behind the radiator. The 10-in. diameter fan blades are one-piece nylon mouldings, each powered by an electric motor instead of being driven from the engine. These motors are governed by thermostat switches fitted in the cooling system, and are so arranged that one fan comes into operation at approx. 80 deg. C. and the second at 90 deg. C. Thus the cooling system can function correctly under any conditions of ambient temperature.

The Corvette engine is fitted with three vertical carburetters, and by a system of progressive linkages only the centre one is operative until half throttle, which corresponds to a road speed of approximately 110 m.p.h., after which all three carburetters come into operation. The prototype is also fitted with a 40-amp. generator, although production models are likely to have an a.c. system.

The large doors are hinged at the lower edge by a spigot resting on a ball, which is adjustable in height to maintain correct alignment of the door. Windows are electrically operated and controlled from a central console, which also incorporates the controls for the air-conditioning unit, radio and subsidiary switches and instruments. An electric tachometer and conventional speedometer are mounted in front of the driver, who, in the prototype, sits on the right-hand side. The bodywork (apart from the engine cowl and boot door, which are aluminium) is made entirely of steel, and houses two ten-gallon fuel tanks at the rear of the car. Initial plans are for the production of some 1,000 cars per year, and the selling price is reckoned to be, on the American market, about $6,000.



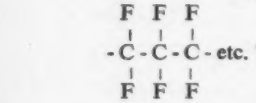
*Left:* Rear suspension, showing swinging links and disc brakes. *Right:* Twin independent cooling fans mounted behind the radiator. The square tubes of the chassis allow easy mounting of accessories.

# FLUORINE CONTAINING POLYMERS

*The development of plastics for engineering purposes is of growing importance to designers. This article deals with some of the outstanding materials already available, and interesting new polymers at present under investigation*

by Prof. M. STACEY, F.R.S. *

THE chemical bond between carbon (C) and fluorine (F) is a particularly strong one, especially where several F atoms are clustered round one carbon atom, as in the group $-CF_3$. Extremely high chemical and thermal stability are characteristics of the saturated fluorocarbon polytetrafluoroethylene $(-CF_2-)_n$ (p.t.f.e., Teflon, Fluon, etc.) which has a very long carbon chain surrounded by F atoms



etc. The size of the F atom is such that in this fluorocarbon molecule the carbon backbone is almost completely shielded by F atoms, and the molecule is quite impervious to attack by oxidising agents such as solvent molecules, acids and alkalis. The macromolecule is in the shape of a rigid rod, and may contain many thousands of carbon atoms in its chain.

A most interesting book has recently been published in America setting out the technology and major applications of resinous fluorocarbon materials. Among the advantages claimed for the polytetrafluoroethylene polymers are:

(a) They are capable of withstanding higher and lower temperatures than more complex resins;
(b) they are chemically inert to both acids and alkalis;
(c) as a group they have excellent moisture absorption characteristics;
(d) the mechanical characteristics are better than average, and
(e) the electrical properties are beyond comparison, and Teflon in particular is the only known material today in the plastics field where the dielectric constant does not vary with the temperature or frequency. Another property which makes it valuable for use in dry bearings is its remarkably low coefficient of friction.

Many difficulties in technology have had to be overcome in order to extend the uses of p.t.f.e. Indeed, it may be said that only "powder metallurgy" is entirely suitable for its processing. It is a type of thermoplastic resin, though it does not melt or flow, which forms a gel at high temperatures and can be self-welded under light pressure. It is supplied in a series of powders for moulding and extrusion, particularly for tape, tubing, wire, insulation, etc., and is also supplied as an aqueous dispersion for giving a non-stick surface to baking tins, frying pans, etc. Valve components made of p.t.f.e. give outstanding performance and long-life service. Many types of gaskets are now made from this polymer.

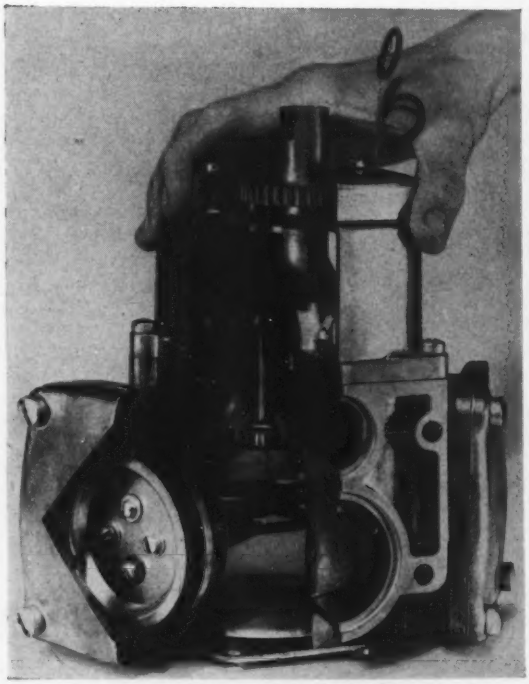


Fig. 1. Cut-away view of a petrol pump meter incorporating a Du Pont Viton O-ring to seal the output shaft which is in contact with high-octane petrol.

Products closely related to p.t.f.e. are derived from polymers of monochlorotrifluoroethylene and are of the general formula $(CF_2\text{-}CFCl)_n$. They are made by polymerisation of monochlorotrifluoroethylene using various techniques, and derivatives can be produced ranging in molecular weight from low-viscosity liquids, greases and waves to solid resins of m.p. 200 deg. C. The solid polymers

* *Chemistry Department, Birmingham University.*

are useful for injection and compression mouldings, film forms and wire coverings.

The low molecular greases and waxes are useful for plasticisers (for the high polymers), greases and lubricants. All these substances have the acid-resistant chemical inertness and non-inflammability of p.t.f.e. In this range Genetron Plastic HL is a crystalline high polymer which is very tough, and which has high compressive strength and excellent abrasion resistance. Polyfluoron is a chemically stable resin with very high dielectric strength suitable for anti-tack applications, while Kel-F is claimed to be a general-purpose, often-transparent plastic with high chemical inertness, high impact strength over a wide temperature range and great resistance to thermal shock.

Kel-F elastomer is a co-polymer of $CF_2 = CFCl$ and vinylidene fluoride ($CH_2 = CF_2$), with a molecular weight range between 500,000 and 1,000,000. Two types of elastomer have been on the market for about four years, and they have excellent chemical and thermal stabilities, though they are swollen by some solvents.

Some polyester types of elastomer have been on the market. They are esters of fluoro diols and dicarboxylic acids such as adipic acid, and have been cured with peroxides. They form good rubbers useful between −70 and 200 deg. C., but perhaps will have a limited use only. Another rubber which is promising, especially since it shows good oil resistance, is a polymer of the acrylate ester of heptafluorobutanol ($C_3F_7CH_2OH$).

The two most promising rubbers are perhaps Viton A and Silastic LS 53. Viton A is a co-polymer of perfluoropropene ($CF_3CF = CF_2$) and vinylidene fluoride ($CF_2 = CH_2$) prepared by an emulsion polymerisation. The polymer is a rubber which is stable up to 300 deg. C., chemically inert, and which has good solvent resistance. It will eventually be made on a large scale. Silastic LS 53 is a fluorosilicone with trifluoropropyl and methyl substituents on the silicon atoms. It has the high-temperature stability of the silicones with excellent solvent resistance. These rubbers will be fairly expensive for some time to come.

### Future Possibilities

A number of fluoro high polymers are still in the pioneer stage. New ground has been broken by a new type of polymer having the general formula $[CF_2\text{-}CF_2\text{-}N(CF_3)\text{-}O\text{-}]_n$

A whole new range of cyclic fluoro compounds including fluorocyclohexenes, fluorocyclohexadienes, fluorobenzenes and other fluoro aromatics has recently been synthesised, and these can form monomers for new polymers. Substances such as $(\text{-}C_6F_4\text{-})_n$ and $(\text{-}C_6F_4O\text{-})_n$ offer good prospects for really high thermal stability. Fluoropolystyrenes with varying degrees of fluorine content, and fluoro analogues of terylene may well be developed for making films with really high thermal stability, for example.

There are great prospects for co-polymerisation. Since the fluorine analogue of almost every known polymer can now be made, it is likely that fluoropolymers will in time find a permanent place amongst thermally stable materials of construction.

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For Further Reading:

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"Fluorine Plastics", *British Plastics*, July 1959, 316-17.
"Viton Fluoroelastomers", *Rubber and Plastics Age*, April 1959, 339.
"Polytetrafluoroethylene", by Fergusson, *Plastics Institute Transactions*, 1949, **17**, No. 29, 11-24.
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"Physical Properties of Teflon", by Doban, Sperati and Sanot, *SPE Journal*, November, 1955.
"Zytel and Teflon as Bearing Materials", by Cheney, Happoldt and Swayne, *Society of Automotive Engineers*, January, 1956.
"Fibrous Teflon", by Farquhar, *Product Engineering*, December, 1959, 190.
"The Mechanical Properties of Teflon at Low Temperatures", by Swanson, *Review of Scientific Instruments*, 1954, **25**, 834.

Fig. 2. Synthetic rubber (left), and Viton O-rings after service at 275 deg. C. in a centrifugal heat exchanger (Artisan Metal Products Inc.).

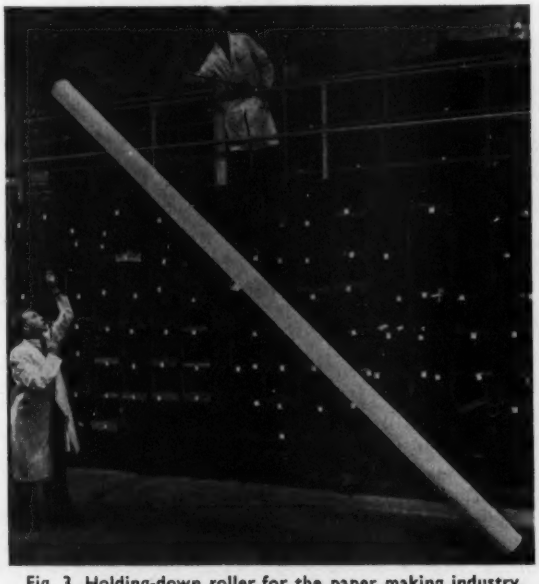


Fig. 3. Holding-down roller for the paper making industry, covered with p.t.f.e. (A.E.I. Woolwich Ltd.).

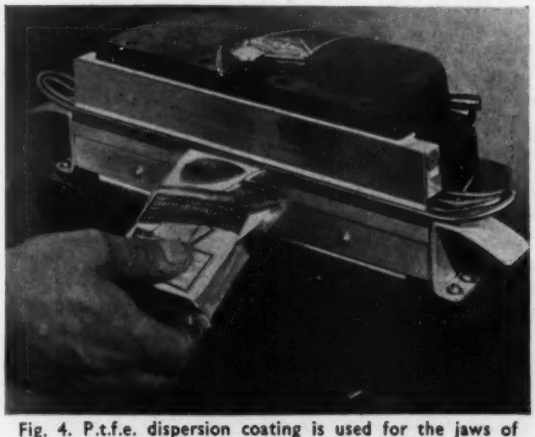


Fig. 4. P.t.f.e. dispersion coating is used for the jaws of this heat-sealing machine, in order to prevent sticking (A. H. Bland Ltd.).

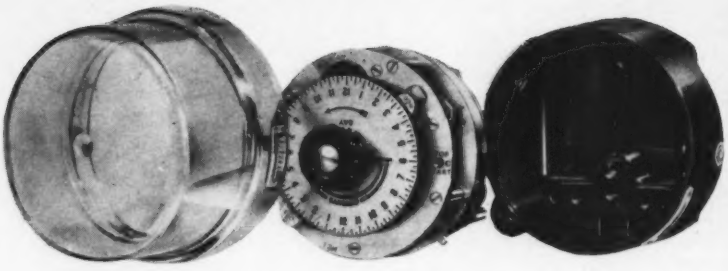


Fig. 1. Sangamo Weston time switch with solar dial and spring reserve.

# INDUSTRIAL PROCESS TIMERS

*Automatic time control is now an accepted part of the engineering process. In this article the characteristics of the various types of unit available are described*

THE term automation is now established in our vocabulary, and the automatic control of industrial processes is accepted as the natural order of things. Such control in a primitive form is probably as old as industry itself; certainly there was nothing new in the idea at the time of the Industrial Revolution, for even then the principle of "delay" or "time lag"—the simplest conception of time control—was widespread in industrial machinery and usually achieved by an adaptation of the gear train and escapement already in a highly developed state as the result of the clockmaker's art. It is a salutary though that in our own generation this basic mechanism is widely used for timing industrial processes, and is only gradually being challenged by the fairly recent introduction of the synchronous electric motor. Indeed, the clockwork movement is never likely to be entirely superseded, since, in conjunction with an electrical winding mechanism, it constitutes an accurate basis for time switching which requires little or no attention, yet is virtually independent of power supply interruptions.

In applications where the requirement is a straightforward and not too protracted delay, the simple pneumatic dashpot is firmly established, while the more complicated timing problems can be tackled with the aid of thermal relays, condenser-discharge timers or electronic timers. The electronic timers now available are largely developed from laboratory equipment devised as an aid to counting and computing at very high speeds, and are capable of performing similar high-speed functions in timing applications. Whereas in the period before the last war there was little need outside the laboratory for timing intervals less than about one-tenth sec. duration, present-day industrial processes frequently demand the accurate and reliable computation of periods measured in milliseconds or even microseconds. Such subdivisions of time are well within the capacity of modern electronic equipment, which not only measure the intervals, but also initiate or cancel operations with an accuracy defined by similar limits.

### Applications of Timing Units

The automatic switching of street lighting is familiar to all, and is the layman's conception of automatic control. Originally conceived in the form of a simple clockwork-operated valve for use with gas lamps (in conjunction with a permanently burning by-pass jet), this type of control has undergone considerable evolution and is now represented by a sophisticated development, the electrically operated solar dial time switch. After one initial setting this switch will continue to run indefinitely, without further attention, switching the lighting on and off throughout the years, and furthermore, adjusting the switching cycle automatically in sympathy with the lengthening and shortening of the day from season to season. During normal operation the escapement is synchronised with the a.c. power supply and therefore keeps perfect time; in the event of power supply failure, the instrument continues to operate and will, if necessary, do so for 30 hours or more, but not under synchronised conditions.

An identical switch differently set up can be used for the control of space heating, reducing the load during the periods when the premises are out of use and if necessary omitting the switching entirely on selected days, for example at week-ends. However, although the automatic control of lighting and space heating can offer a useful contribution to industrial economy, the true worth of automatic timing manifests itself in other applications. A notable example is the accurate timing of the various sequences in the electric resistance welding process. Besides relieving the operator of the need to time his own various actions and thus minimising fatigue, automatic timing offers an accuracy quite unobtainable where the human element has to be considered; with some materials this degree of accuracy is vital to the success of the weld, and with others the timed periods are so short that they would, in any event, be beyond the powers of human measurement.

It is probably true to say that the correctly phased application of heat, directly or indirectly, offers the greatest opportunities for process timing equipment in industry today, whether it is the high-energy pulse lasting a mere fraction of a second used for welding electrodes in a thermionic valve, or the prolonged soaking at elevated temperatures necessary for the heat treatment of certain metallic alloys, more consistent results can invariably be obtained by intelli-

*Data by courtesy of C. J. Foote & Partners Ltd., Bournemouth.*

gent use of automatic timing. Automatic control of machine tools enormously increases the productive capacity of the equipment and produces a higher repetitive accuracy and quality of finish. In the rubber and plastics industries the close control of intimate mixing and curing ensures the very necessary homogeneity of these products; the filling of containers at the end of a manufacturing process is achieved more cleanly and speedily and with far greater accuracy; conveyor belts controlled in sympathy with the actual output at any time prevent bunching, which wastes time and can lead to breakdown. Other applications which come to mind are the control of immersion periods in electro-plating processes, ratio control of reflux distillation columns, and the control of exposure and development timing in large-scale photographic and lithographic processing.

A detailed assessment of applications most suited to the various types of control unit available is not possible in a limited space, and this survey briefly describes the more important devices now on the market. In this connection it is appropriate to classify the units, which fall very roughly into three broad groups, viz.:

Delays, which, as the name implies, merely postpone the inception of a process or operation by a predetermined time interval.

Interval timers, which set a process in motion as soon as a control switch is operated, and stop the process after a predetermined time interval.

Sequence timers, designed to start, stop and re-start an operation or series of operations according to a preset pattern. At the end of the pattern the cycle can be repeated indefinitely, or the device can be arranged to await a further initiation signal.

The functions of all three groups are to some extent interchangeable. By rearrangement of switch or relay connections, it is possible to adapt an interval timer of the time-switch variety as a delay, and vice-versa; on some sequence timers one section can be isolated and used on its own as either a delay or an interval timer. Further, the functions of both delay and interval timing can be combined in one instrument if necessary.

In the choice of a suitable timer for any particular application a number of factors must be considered if an intelligent selection is to be made. There is an enormous range to choose from, and although for most applications there may be many different units each capable of executing the required sequence of operations, it is likely that for certain specialised tasks there will be one, and only one, unit that will be entirely satisfactory. It is worth while going to the little extra trouble to track down this one specimen. Should the entire available range fail to produce the required article, many manufacturers are prepared to study a customer's problems to the extent of designing a special unit for his particular requirements.

As a general rule, timers employ electrical switches as the means of controlling the various operations, but instruments embodying pneumatic selector valves are also available and can be connected directly into the air control circuits of pneumatically operated or controlled machines.

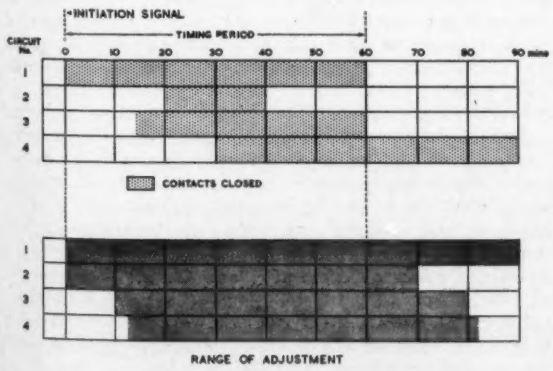



Fig. 2. Typical timing diagram for an application involving the sequential switching of three circuits under the master control of a fourth.

## Information Necessary for Correct Selection

TIME RANGE—Clearly, the first consideration is the range over which the appliance is to be capable of operating. Although the flexibility of modern units permits adjustment over a usefully wide range, it must be borne in mind that the minimum time that can be set up with accuracy is largely dependent upon the maximum possible setting. A maximum-to-minimum range of 10 to 1 or 20 to 1 is an average figure in units of the non-electronic type. For example, two specimens selected at random from a range of motor-driven timers claim setting ranges of 1 to 10 seconds and 30 minutes to 6 hours, respectively, but range ratios of 60 to 1 are not uncommon. By using two or more similar instruments in a cascade arrangement the range can be extended indefinitely, and because of the ease with which this can be arranged in the electronic type of timer, this feature is frequently fundamental to these instruments and accounts for the very wide range of setting available. Some motor-driven timers are produced with alternative ranges; for example, one specimen has a basic range of 0 to 6 seconds, quickly changeable to 0 to 6 minutes.

ACCURACY—The average spring or motor-driven timer has an accuracy of about 1 per cent of the total range, though certain of the higher-grade instruments have a quoted accuracy as good as $\frac{1}{4}$ per cent. Far greater accuracies are obtainable with electronic equipment, however, and this property is particularly useful where a timer is required to repeat indefinitely a set sequence. Repeat accuracies of the order of 0·01 per cent are claimed for many units of this type.

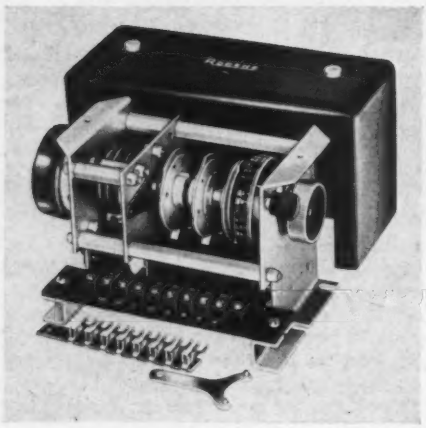
An electronic timer used as a process timer in the literal sense, i.e., with its output employed actually to initiate a process rather than merely to compare it with a calibrated time scale, must be used in conjunction with relays. The natural delay inherent in every type of magnetic relay must be taken into account when the accuracy of an installation is being assessed. Relays having extremely fast rates of operation are now readily available.

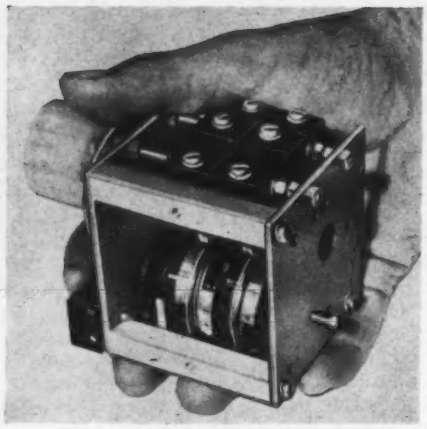
The slow ageing process to which electrolytic condensers are prone tends to reduce the long-term accuracy of timers of the condenser-discharge type. For this reason some makers market models upon which the dial is arbitrarily calibrated in figures from 1 to 10 or 1 to 100, or as the customer may require.

When considering a synchronous motor timer, it must be borne in mind that maximum accuracy is obtainable only if the motor is running continuously. Even in the best of motors the run-up time is a measurable quantity, but it must be admitted that in the majority of applications for which a motor-driven timer would be used this time-lag can be ignored.

SUPPLY CURRENT CONDITIONS—If an electrical timer is contemplated (synchronous motor, condenser discharge or electronic) the voltage and frequency of the supply will need to be specified, and in any timer (electrical or otherwise) having an output in the form of switch contacts, the handling capacity of those contacts must be borne in mind, suitable contactors being introduced to carry the load if necessary.

CONTACT SEQUENCE—A timer required for switching on or off one circuit and repeating the switching cycle if necessary is a comparatively uncomplicated piece of machinery; many suitable models are on the market and selection is merely a question of the desired range and accuracy. However, for a process demanding the simultaneous control of many





*Left:* Fig. 3. Rodene miniature synchronous-motor cam-operated sequence timer.

*Right:* Fig. 4. Elremco miniature heavy-duty timer, type ZX.

operations in a closely controlled sequence, more elaborate equipment is called for and more careful selection is necessary.

As a first step in the selection of a timer for a specified purpose it is advisable to draw up a timing diagram on the lines of the one shown in Fig. 2. The upper diagram represents the required sequence, while the diagram below it indicates on the same scale the range of adjustment available with a suitable timer. The requirement shown in the diagram is for a four-circuit multiple timer in which the overall timing is controlled by circuit No. 1 (i.e., timing takes place only when No. 1 circuit contacts are closed), the other circuits operating as follows:

Circuit No. 2—Close at 20 minutes, reopen at 40 minutes.
Circuit No. 3—Close at 15 minutes, reopen at 60 minutes.
Circuit No. 4—Close at 30 minutes and remain closed until the instrument is reset.

Since No. 4 circuit is to remain closed, timing is arranged to cease at 60 minutes, when the last timing operation takes place (i.e., opening of circuit No. 3). Although the adjustment range diagram reveals an upper setting limit of about 82 minutes for circuit No. 4, this does not matter since in this application there is no requirement for timed breaking of this circuit.

It will be appreciated that it is usually possible for any desired arrangement of normally-open or normally-closed contacts to be included in any one instrument, although the requirement in the example above is assumed to be for all contacts to be normally open. The range of adjustment, like the overall range, varies considerably between the various models on the market, but a spring- or motor-driven timer can usually be reckoned on to provide reliable timing down to about 1 second; shorter periods than this are better catered for by electronic means.

Environment—Most timers now in production are largely unaffected by environmental changes, but it is advisable nevertheless to specify the location of the proposed installation, whether any item is to be readily accessible (e.g., for frequent changes of programme) and whether the installation as a whole is to be flameproof or weatherproof. Many models are available completely weatherproofed either by hermetic sealing of the case or by immersion of the mechanism in oil.

Resetting Requirements—A desirable feature of any timer is the ability to return rapidly and accurately to the "zero" setting, ready for a further sequence. Furthermore, the resetting action must not upset the adjustment of the device. In mechanical timers the resetting control usually takes the form of a knob or lever attached to the instrument, while in electrical timers controlled by a remote switch the opening of this switch usually resets the mechanism. Some types, however, are so arranged that resetting can take place only upon the completion of a sequence; this may or may not be automatic, but in either event it must be borne in mind that interruption of the supply current in mid-sequence will prolong the timed period for as long as the interruption lasts, the mechanism re-starting and completing the sequence when the supply is restored.

### Types of Timer Available

Mechanical Timers—The simplest device to which the connotation process timer can be applied is the mechanical delay, or time-lag as it is sometimes called. A popular form of this type of appliance operates on the principle of the pneumatic dashpot, in which a loaded piston or diaphragm displaces air at a controlled rate through a variable orifice. The device is set mechanically, electrically (by means of a solenoid) or pneumatically (by admitting air under pressure in the reverse direction). Due to their simplicity, these timers are reliable and practically everlasting, and are useful in applications where the requirement is for timing ranges extending from 1 second to about 5 minutes, and where extreme accuracy is not essential. Other mechanical types operate on the principle of the rack-and-ratchet or rack-and-escapement; these are usually designed for direct connection to, for example, the control lever of a switch, and an internal spring usually resets the mechanism immediately the load is removed.

A spring-operated gear train with an escapement mechanism at the output end provides a useful basis for mechanical timing units (the ordinary clock is an example of this). Extreme versatility is available by merely varying the gear ratios. A well-made escapement timer will give good results over a range extending from a few seconds to several hours, but for short timing periods where extreme accuracy is not required, the escapement can be replaced by a rotating air-vane, which has a wide and easily adjusted speed range.

In its simplest form the spring-and-escapement timer resembles the domestic alarm clock and is about as accurate. Turning the dial or pointer to the required period winds the spring, which then carries the pointer back to zero and rings a bell. More accurate versions have good-quality escapements and are equipped with robust electrical contacts for direct process control. Also available are excellent examples in which the spring-wound movement operates continuously (as long as the spring is kept wound), the timing operations being accomplished by means of cams or pre-notched discs in precisely the same way as with synchronous electric motor timers, dealt with in the next section.

Synchronous Motor Interval Timers—The elementary synchronous motor timer has, like its clockwork counterpart, a calibrated dial and a pointer which, on being set to

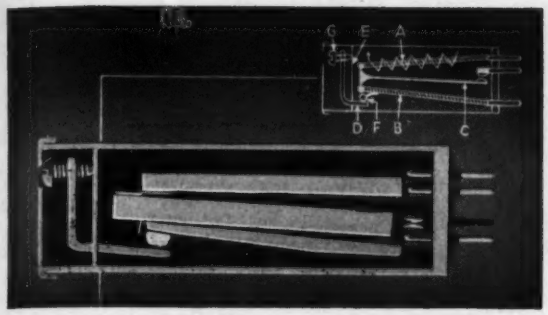



Fig. 5. Mechanism of a precision thermal delay relay (Coventry Controls).

Fig. 6. Electronic synchronous timer for use with welding machine (South London Electrical Equipment Co.).

the required time period, is carried back to zero by the action of the motor, and there operates a contact which marks the end of the timed period and also stops the motor. The more refined versions are usually remotely controlled by an external initiation switch, which on being closed operates an electromagnetic clutch and causes the pointer to move back to zero at a strictly controlled rate under the influence of the synchronous motor, which rotates continuously. On reaching the zero position of the pointer the mechanism operates a relay controlling the load circuit, and the design of the mechanism is usually such that resetting of the pointer is automatic; it flies back immediately and reassumes the setting position ready for the next signal from the initiation switch.

A separate setting pointer—usually of a distinctive colour—is sometimes provided. During the setting process both pointers move together to the selected position, but only the timing pointer returns to zero when the initiation switch is operated; the setting pointer remains in the set position and the distance between it and the timing pointer indicates the elapsed time at any instant.

Some timers are so arranged that the motor is at rest until the initiation switch is operated. Although the running-up time of present-day motors can be ignored as a factor affecting the average timing requirement, its existence must be taken into account in applications demanding extreme accuracy of the timed periods.

SEQUENCE TIMERS—The synchronous motor timers so far discussed are limited in their application to simple switching operations involving one process. Although adaptable, the more involved cyclic timing processes are better accommodated by timers of the rotating camshaft type. Even one calibrated timing disc rotating at a controlled speed can provide the means of switching many circuits sequentially, by the agency of variable cams rotating with it. It can introduce additional cams driven at different speeds (by take-off from other parts of the gearing), and the most complicated sequential switching programmes can be dealt with reliably and with considerable accuracy. Provided that no interruption of the supply occurs, a timer of this type will continue to monitor a predetermined sequence indefinitely. Routine adjustments to particular sequences are easy to carry out, and in some models the overall programme is dictated by readily interchangeable timing discs which are available to stock patterns or to specification.

As a precaution against possible supply failure some timers incorporate a spring reserve, which takes over automatically if the supply is interrupted and is capable of operating the device for 30 hours or more. In some installations, however (for example, where the process itself depends upon an uninterrupted supply), this feature is unnecessary and perhaps undesirable.

Some forms of cam timer are arranged so that the cams do not rotate continuously, but are returned to the zero position by spring action after a preset arc of travel. In some applications this feature is an advantage in that the set periods do not have to be related to the total camshaft rotation period.

A disadvantage of a multi-cam timer in which all the cams rotate at the same speed is that as the total range is limited to the camshaft rotation period there is a very definite restriction on the number and accuracy of the individual timings available. This limitation is avoided in the impulse-sequence controller. A notched and calibrated master timing disc rotates continuously, operating a microswitch at the notched positions selected for the impulses. Each electrical impulse, operating in conjunction with the index cam rigidly attached to the left-hand end of the camshaft, causes the camshaft to rotate through 30 degrees and then stop until the next impulse is received. The camshaft therefore rotates in steps, the periods between the steps (controlling the durations of the process stages) being dictated by the relative positions of the notches on the timing disc. In an electro-pneumatic timer the electrical switches are replaced by pneumatic selectors.

CONDENSER DISCHARGE TIMERS—These employ as their basic principle the time constant of a condenser/resistance combination, and operate by the condenser discharging through a relay. Variation of the timed period is achieved by altering the value of a resistance connected either in series or in parallel with the condenser. Due to their simplicity and their freedom from influence by stray magnetic fields, these timers are suitable for many applications where the conditions do not permit the employment of motor-driven or electronic timing equipment. The maximum setting period is about 60 seconds, and because of the gradual variation in characteristics caused by the slow but inevitable ageing of electrolytic condensers as used in these instruments, it is frequently found that the setting dials are provided with arbitrary calibration only.

ELECTRONIC TIMERS—In its simplest form the electronic timer utilises an extension of the condenser discharge principle in that the condenser is in the grid circuit of a thermionic valve. Closing an external switch (which may be mounted remotely from the instrument) connects the supply to the condenser via the resistor; after the time dictated by the relative values of these two components the charge on the condenser is sufficient to trigger the valve. A relay in the anode circuit of the valve then conducts and

controls the timed circuit. Alternatively, the circuit can be arranged so that the valve conducts, and the relay operates, as soon as the control switch is closed. The condenser charge leaks away through the variable resistor until at some predetermined point the valve ceases to conduct and the relay returns to its normal condition.

If arrangements are made for a signal to be fed back from the anode to the grid of the valve the device will reset itself automatically and repeat the timed cycle indefinitely; it becomes, in effect, a variable low-frequency oscillator possessing useful potentialities in the timing field. Electronic instruments based on the above principle were originally developed as laboratory equipment and later as industrial counting devices, and their usefulness has for some time now been extended into the realm of process timing, and particularly electric welding, where the timed periods may be very short and must be controlled with great accuracy, as must the periods between them. The precision obtainable with this type of timer is far beyond the scope of any device subject to the inertial embarrassment of moving parts in its timing stages. Moving parts in the form of relays, contactors and other control gear are of course necessary in the later stages, and it is customary for manufacturers to build up as one assembly all the units necessary for a particular application. Other associated units for occasional use only, such as an up/down slope control for a weld timer, can be plugged in as required.

This class of heavy-duty controller occurs in two main forms, synchronous and non-synchronous. Synchronous timers are used where one or more of the timed energy pulses are so short that each extends over less than about two cycles of the power supply, i.e., 40 milliseconds on a 50-cycle supply. The pulse is synchronised with the power supply waveform so as to avoid the variation in weld heat which would otherwise occur from pulse to pulse.

Equipment of this nature is not necessarily confined in its application to weld timing, and since any reasonable number of timing stages can be incorporated in one instrument, each stage being capable of extreme accuracy and stability, it is conceivable that electronic timers will in time invade territory at present very strongly held by motor-driven equipment.

SHELF LIFE OF ELECTROLYTIC CONDENSERS—Since the satisfactory operation of many condenser-discharge and electronic timers depends upon the correct behaviour of electrolytic condensers, the "shelf life" of these components is of considerable significance. Prolonged periods of inactivity usually effect first a gradual increase or decrease in capacity, followed by a sudden decrease. Suitable treatment will restore the rated characteristics, but an instrument put into service without this precaution will be subject to inaccuracy and the possibility of breakdown associated with irreparable damage to the condensers.

THERMAL DELAY RELAYS—As originally conceived, the thermal delay was intended as a cheap and convenient means of delaying the operation of electrical contacts; its accuracy was of a very low order and was further affected by changes in the ambient temperature. The introduction of the differential principle largely counteracted this latter failing, but, even so, the device was not taken seriously as a means of process timing. However, the decision on the part of certain manufacturers to develop the thermal relay as a precision delay has resulted in an accurate timing device possessing many exclusive features; for instance, it is small and light, can be easily hermetically sealed, can be operated off d.c. or a.c. of any frequency, and has no lubrication problems, a factor to consider where operation at extreme temperatures is envisaged.

Its principal disadvantages lie in the fact that a single unit used alone must be allowed to cool before a timing sequence can be repeated (i.e., quick resetting is not possible), and it is sensitive to slow fluctuations of the supply voltage. In certain applications, however, the incapacity for quick resetting is of no significance, and in others the response to any slow voltage fluctuations provides a useful degree of self-compensation where the controlled process is itself affected by the fluctuations. By the use of two or more relays working in conjunction with one another, both of these limitations can be overcome, if necessary.

Fig. 5 shows the construction of a typical hermetically sealed relay. Two members A and B have the same coefficient of expansion. A is the actuating member, equipped with the heating element. Any difference in expansion between these two members moves the contact arm C into or out of engagement (in the example shown the contacts are normally open). Contact operation takes place in a fixed time regardless of the starting temperature. An adjusting arm D is silver brazed into the diaphragm E to enter the hermetically sealed space. The inner end of this arm bears against the pivot structure at F; turning the adjusting screw G changes the initial contact gap and with it the operating time.

A thermal delay is designed for one nominal setting, the adjusting screw being for fine adjustment only. Although settings up to 25 per cent either side of the nominal operating point of the relay are available in some relays, the manufacturers usually advise that the setting should be as close as possible to the nominal value so as to avoid interference with the other quoted characteristics.

Combinations of more than one thermal relay, or of thermal and magnetic relays, are commonly marketed as units for specific purposes.

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*PRINCIPAL BRITISH SUPPLIERS OF PROCESS TIMERS*

**Allied Electronics Ltd.**
*Weld control timer* with four adjustable periods and autocycling facility.
*Industrial process control timers*, several models covering the range ½ second to about 5 minutes. Repetitive accuracy ±½ per cent.
*Industrial process controllers* for intervals 0·1 second to 15 minutes, with facility for "ring" connection of any number of timers for automatic successive operation.
*Two-period timer* with repeat facility.
*Electronic two-cycle process timer*, which alternates continuously between two time settings, independently adjustable.
*Thermal delay vacuum switch*, maximum delay 120 seconds.
*Sequence switch*. Two relays operate and release continuously. The space ratio of each relay and the phase relationship between the two operations are adjustable.

* * *

**Associated Electrical Industries Ltd.**
*Synchronous motor timers*, self-resetting, with electromagnetic clutch. Ranges covering periods 1 minute up to 60 minutes. A direct-current version with mechanically governed motor is also available.
*D.c. time lag relays*, ranges up to 20 seconds with single contact or with additional independent "passing" contact. Also available is a model with a continuously-rated solenoid.
*Electronic timer*, in four versions covering the ranges from 0·3 up to 180 seconds.

* * *

**Atkins, Robertson & Whiteford Ltd.**
*Electronic timer*, usually supplied in a four-stage model for welding control, but any number of stages can be included. Incorporates facility for sequence repetition. Each stage calibrated 0–180 cycles with fine adjustment.
*Electronic millisecond timer*. Primarily a recording instrument, but can be used in conjunction with relays to perform batch counting, etc., with extreme accuracy.

* * *

**Camerer Cuss Ltd.**
*Clockwork short-period timers*, ranges up to 60 minutes.
*Clockwork time switches* for direct insertion in supply sockets. Ranges up to 12 hours
*Clockwork two-unit time switches*. Independent setting of On and Off on separate dials. Ranges up to 12 hours.
*Electronic timer*, with automatic resetting and sequence repetition. Ranges up to 15 minutes. Cold cathode valves permit timer to be left "ready" indefinitely.

* * *

**Cass & Phillip Ltd.**
This firm specialises in elapsed time indicators, which, though not strictly process timers, are nevertheless directly applicable to industrial processes.

* * *

**Chamberlain & Hookham Ltd.**
*Synchronous motor timers* with planetary gear system and electro-magnetic clutch. Type P for extreme accuracy—range 0·1 second to 48 hours. Type C for applications demanding less accuracy—range up to 100 minutes.
*Mechanical time delay switch*. Range up to 2½ or 5 hours.
*Synchronous motor time switch* with 24-hour dial. Can be supplied with solar dial and/or day selective device.

* * *

**Coventry Controls Ltd.**
*G–V thermal relays*. These relays operate on the differential principle, and are sufficiently stable and accurate in their operation to be used as process timers. They are available in both factory-set and adjustable versions, with operating voltages from 1·5 to 230 and ranges up to 180 seconds.
Combination relays comprising two or more thermal relays and electromagnetic relays are available for applications requiring instant resetting, sequence timing, etc.

**John Davis & Son (Derby) Ltd.**
*Electronic timers* covering the range 0·3–180 seconds. Can be used for all types of process and machine timing, as well as in conjunction with photo-electric relays. The certified FLP enclosures used make the timers suitable for operation in the Group I and II atmospheres of coal mines, petroleum plants, etc.

* * *

**Elcontrol Ltd.**
*Electronic process timer* with automatic resetting. Range up to 5 minutes. Available in calibrated or uncalibrated form, and with various conditions of initiation.
*Electronic delay switch.* This is similar to the above, with the difference that the relay contacts remain inoperative until the end of the set time.
*Cyclic timer.* In effect two single timers in one, each triggering the other and thus producing a constantly repeated sequence. Independent operation of the two units can be arranged if required.
Special sequence control installations are designed and produced to customers' requirements.
*Electronic high-speed batch counter*, which can be adapted as a process timer or a cyclic timer.

* * *

**Electrical Remote Control Co. Ltd.**
*Hand-set synchronous motor timer*, set by turning the dial pointer to the required time for each operation.
*Automatic single-period synchronous motor timers* with ranges from 0–15 seconds to 0–28 days. Automatic reset within ½ second of the end of the time period, or on supply voltage interruption.
*Automatic multi-period cam timer*, controlling up to twelve changeover contacts, each independently adjustable. Automatic resetting as for single-period timer (above), or alternatively the cycle can be set to repeat continuously. Standard ranges 0–10 seconds to 0–28 days.

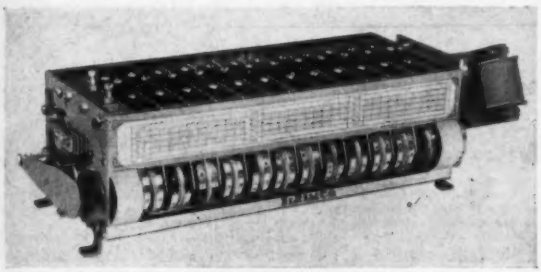


Fig. 7. Elremco multi-circuit timer type MAT/RM/RS.

*Motor-driven mercury-switch timer*, in which the cams operate tilting mercury tubes, permitting switching up to 30 amps at 440 volts a.c. No limit to number of cams; shaft speeds from one revolution per second to one revolution in 28 days.
*Condenser timer (non-electronic).* Control of up to twenty-four make, break or changeover contacts, set up independently on an arbitrarily calibrated dial. Ranges from 0·2–2 seconds to 5–60 seconds.
*Automatic time-delay.* Solenoid-operated mechanical escapement operating a changeover switch at the end of the adjustable time delay. Time range 1–10 seconds up to 1–10 minutes.
Any of the above instruments can be supplied in flameproof enclosures Buxton Certified for Groups II and III.

* * *

**Electronic Machine Co. Ltd.**
*Electronic non-synchronous timer* for temperature control, welding control, solenoid valve operation, etc. Automatic or hand reset; range 60 milliseconds to 30 minutes.
*Precision timer* controlled by 10 kc/s crystal. Dekatron display, range as required. Overall accuracy ±0·005 per cent. Auto-cycling and chart recording facility.

* * *

**Electronic Switchgear Ltd.**
*Electronic interval timers*, range coverage 0·5–100 seconds, with manual or automatic resetting.
*Delay timers.* Range coverage 1·5–30 seconds delay.
*Repeat cycle timers*, comprising assembly of two interval timers operating alternately.
Ranges: 1·5–30 seconds on both dials,
or 5–100 seconds on both dials,
or 1·5–30 seconds on one dial,
5–100 seconds on the other.

* * *

**Elkay Electrical Manufacturing Co. Ltd.**
*Pneumatic time lag switches* in various forms.
Ranges from 1 second to 5 minutes.

* * *

**Elliot Brothers (London) Ltd.**
*Cycle controller* for plastics presses, consisting of a multi-cam timer for opening and closing presses, etc., combined with a synchronous motor process timer. Ranges 20 seconds to several minutes. Exceptional ease of adjustment and above-average accuracy.
*Impulse-sequence controller*, designed for processes where a number of factors must be controlled very accurately against a fixed time schedule. Interchangeable timing discs permit rapid changes of programme within the range 0–15 minutes to 0–360 minutes.
*Single-cam cycle controller*, for applications involving four or fewer process factors, and where frequent cycle changes are not required. An air-operated version is available for such applications as moulding presses for rubber heels.
*Multiple-cam cycle controllers*, with almost any number of cams, are supplied to customers' requirements. These are intended for use on complicated processes operating continuously for long periods under fixed conditions.

* * *

**Engel & Gibbs Ltd.**
*Synchronous motor process timer*, adjustable from 0·3 second to 6 hours. Four changeover contacts for delayed or undelayed switching.
*Escapement process timers*, ranges from 0–10 seconds up to 18–180 seconds.
*Mercury switch time delay relays*, ranges 0–15 seconds to 60–180 seconds.

* * *

**Equipment & Services Ltd.**
*Special-purpose timing and control devices*, to specification.

* * *

**Evans Electronic Developments Ltd.**
*Electronic timer* utilising thyratron valve. Timing ranges from 0·1 second up to 3 minutes.
*Electronic sensitive relay.* Up to 8 amps output capacity for an input of 5 microamps. Suitable for process control where delicate limit switches are unavoidable.

**Gensign (General Signal & Time Systems Ltd.)**
Catering mainly for customers' individual requirements, this firm also has in its standard range a hand-set synchronous motor timer (0–30 minutes), and a precision timer for laboratory and refinery work.

* *

**Gunfire (Automatic Light Controlling Ltd.)**
*Hand-set synchronous motor timers*, ranges 0–4 minutes up to 0–12 hours.
*Synchronous motor cam-operated process control switch.* With a wide choice of gear trains and easily interchangeable cams, a practically unlimited variety of operations can be achieved. Cam rotation speeds—from one revolution per second to one per day.
*Synchronous motor multi-cam sequence controller.* Easily adjustable for range; switch contacts can be up to 20 amp capacity according to requirements.
*Synchronous motor time switches*, 24-hour dial. Available with solar dial.
*Spring reserve time switches.* 24- and 72-hour reserve models, available with solar dial and day selective device.

* * *

**Hirst Electronic Ltd.**
Synchronous and non-synchronous electronic welding control timers, and associated equipment for all types of electric welding.
*Ignitron controllers (synchronous).* Using printed circuits, this timer produces the extremely short welding times (up to ¼ cycle) required for non-ferrous materials.
*Welding or process timer (non-synchronous).* Uses printed circuits and high-stability cold cathode valve. Standard frequency range 2–15 cycles covering periods up to 3 seconds.
*Thyratron controller (non-synchronous).* Range ¼ to 9 cycles with phase shift heat control, giving 100:1 power ratio over entire timing range. Designed for high-precision spot welding.

* * *

**Edward Holme & Co. Ltd.**
*Solenoid-operated delay relays* (rotary type).
*Motor-operated timers.* These components are designed primarily for use in conjunction with starting equipment for electric motors, but they can be adpated for other timing applications.

* * *

**Horstmann Gear Co. Ltd.**
*Synchronous motor time switches*, single or dual circuit, with optional solar dial or day selective device.
*Spring reserve time switches* with 12-hour reserve.
*Hand-set synchronous motor time controller.* Operating period up to 14 hours (Mk.III.) or combined with optional delay of up to 4 hours (Mk. VI). Contact rating 30 amps at 250 volts.

* * *

**Kelvin Hughes**
*Pressure and temperature controllers*, basically on/off devices incorporating cam-operated programme timers mounted integrally with the recording instruments.

* * *

**Landis & Gyr Ltd.**
*Synchronous motor timer*, with separate setting pointer for indicating elapsed time; also built-in counter for integrating the periods of operation.
*Synchronous motor time switch with spring reserve.* This differs from the normal spring-reserve switch in that under normal conditions the mechanism is controlled directly by the synchronous motor, the escapement being brought into action only in the event of supply failure. The reserve period of 12 hours can be extended if necessary by hand winding. Solar dial and external adjustment for off-peak periods, among other features.
*Synchronous motor contact clock*, with one, two or three contact switches operating independently. Solar dial available.
*96-hour reserve electrically-wound time switch.* Solar dial and many other optional additional features available.

* * *

**Loblite Ltd.**
*Watertight time switch*, range 1–5 minutes, for direct insertion in wiring installation. Used mainly for staircase lights, etc., but could be adapted for approximate industrial timing.

* * *

**Londex Ltd.**
*Synchronous motor process timers* to cope with practically any conceivable timing application. Included in the range are hand-set timers, self-resetting and cycling period timers, and energy regulators. Of particular interest is the high-accuracy Model ASR, eminently suitable for applications where it is necessary to have a number of timers grouped remotely from the machines they control, and a high-precision model (DST) having a double scale which simplifies setting. A new instrument recently introduced is the type IMP, which is self-resetting with a wide variety of contact arrangements.
*Cam-operated multi-circuit timers* with up to 30 cams are produced to customers' requirements.

Fig. 8. Londex unit for domestic and industrial installations.

*Condenser timers* for a.c. or d.c. Ranges from 0·1 up to 60 seconds with an average maximum/minimum ratio of 10:1.

This firm also manufactures photo-electric equipment and high-speed electronic counting apparatus.

* * *

**Magnetic Controls Ltd.**

*Resistance-capacity timers*, ranges ¼–60 seconds.
*Thermal switches*, low accuracy only. Ranges from 5 seconds to 2 or 3 minutes.
*Electronic timers*. Ranges from a few seconds to one hour or more.
*Electro-mechanical relays*. Ranges from ¼ second up to 5 minutes.
*Mercury tube delays* (non-adjustable). Time periods from 1 second up to 1 minute.

Most timers can be fitted with a number of contacts each having a switching capacity of up to 30 amps.

Complete process and other controls to meet customers' specifications are also produced by this company.

* * *

**Martonair Ltd.**

The timers produced by this organisation are intended for use in conjunction with pneumatic cylinders and other devices.
*Hand-set clockwork timer* with solenoid-operated valve which opens (or closes) at the end of the period set up on the dial.
*Pneumatic timer* (*dashpot*). Resetting is by push-button, air pressure signal or electrical impulse. Normal ranges of 5 seconds up to 4½ minutes can be extended almost indefinitely by the addition of external reservoirs.
*Timing circuits* incorporating pressure switch, flow regulator and reservoir can be made up for applications requiring a delay or dwell, rather than an extremely accurate interval, in a pneumatic installation.

* * *

**John Morris Electrical Engineering Co. Ltd.**

*Heavy-duty time delay relays* with a large variety of contact arrangements. Delay ranges from 0–1 up to 0–300 seconds. Suitable for a.c./d.c. working up to 660 volts.

* * *

**M.T.E. Control Gear Ltd.**

*Electromagnetic relay*. Ranges 0–60 seconds and 0–3 minutes. Provision for four sets of contacts—two delayed and two instantaneous. Individual vernier adjustment of delay contact provides step delay up to 75 per cent of basic setting.
*Condenser-resistance time delay relays* for a.c. or d.c., readily adjustable. Standard ranges from ¼–6 seconds after energising or 2–20 seconds after de-energising, or a combination of both, repetitive. Other ranges available to special order.

* * *

**National Time Recorder Co. Ltd.**

In addition to a variety of time recording instruments, this company produces a programme instrument for the electrical actuation of warning or other devices at intervals of 5 minutes upwards.

* * *

**The Power Equipment Co. Ltd.**

*Vacuum-operated time delay switch*, adjustable from 2 seconds to 1 hour.

* * *

**Radiovisor Parent Ltd.**

*Four-stage resistance capacity weld timers.*
*Electronic weld control timers.*
*Ignitron contactors for use with weld timers.*
*Plug-in units for weld controllers*, giving up-down slope control, heat control, up-slope with heat control, current regulation, and up-down slope with current regulation.

This company specialises in the design of weld control equipment for particular applications, and also manufactures photo-electric timing and counting equipment.

* * *

**Reason Manufacturing Co. Ltd.**

Hand-wound precision time switches, up to 30 hours endurance with contacts rated at up to 75 amps. The switches are enclosed in dustproof and watertight cases. Some models can be supplied with a day selective device.

* * *

**Rodene Electrical Co. Ltd.**

*Instant reset synchronous motor timer* (type 7000), with solenoid-operated contrate wheel clutch and three sets of contacts each operated in a different manner. Ranges 0·5 second up to 3 hours.
*Self-reset synchronous motor timer* (25 series). Resetting takes place upon interruption of the supply, and can be arranged automatically by the inclusion of a relay. Two timers working in conjunction will provide cyclic operation. Ranges from 1 second up to 10 minutes, with resetting times up to 7 seconds, according to type.
*Multi-circuit cam timers*, available for a.c. or d.c. operation. There are three main types: (a) in which the camshaft rotates continuously; (b) in which camshaft rotation is limited to 300 degrees, interruption of the supply causing it to return to zero under the influence of a spring at a rate dependent upon the setting; and (c) similar to (b) but fitted with an electromagnetic clutch which permits the camshaft to reset instantly. Cycle times range from 3·6 seconds to 1 week; the number of cams capable of being accommodated depends upon the range required, but for set periods of more than about 2 minutes, up to 24 cams can be fitted.

The company has recently introduced refined versions of their basic cam mechanisms for cyclic timers known as Varicams. These feature quicker, closer and more accurate setting, and long-life fully-floating bearings. Other recent introductions are Minicams, intended for quantity production applications, and Magnacams, which are larger, de-luxe versions of the Varicam with even better setting facility and accuracy and easily-removable switches which can be replaced by pneumatic valves if necessary.

* * *

**Rotherham & Sons Ltd.**

*Mechanical time lags*, variable and non-variable. These time lags operate on the principle of a rack-operated gear train with either an escapement or a rotating fan at the "fast" end. They are all intended for direct connection between a control and its operating load, and are arranged so that at the end of the controlled delay the connecting member breaks with the "clockwork", thus providing a smart action. The return action is instantaneous. Variations in applied load will affect the delay for a given setting of the instrument (details can be obtained from the makers).

* * *

**Sangamo Weston Ltd.**

*Synchronous motor time switches*, with 24-hour dials and a variety of contact arrangements. Up to three pairs or sets of levers (i.e., three circuits switched On and Off) can be accommodated; some switches are arranged for three-cycle sequence switching of two circuits. A solar dial, day selective device and fixed-interval levers are available for most models.
*Spring reserve time switches*, with general features as above. The carry-over period is approximately 18 hours, and an exclusive feature is that the movement is under synchronous control during normal operation.
*Hand-set synchronous motor interval timers*. Five standard models with ranges from 0–55 minutes up to 0–22 hours. Synchronous motor time switches with 1-hour, 3-hour, 6-hour or 48-hour dial. These are similar to the 24-hour dial model except that the solar dial and day selective device are not appropriate.
*Short interval single-circuit time switches*. Operated by synchronous electric motor, these cam-type switches are available with a timing range of either 5–75 seconds or 75–130 seconds, and a selector disc enables an interval of 5, 10, 15, 20, 30 or 60 minutes to be obtained between operations.

All time switches except the short period models can be manually operated by means of a button, which selects the operation that the switch would otherwise have performed next.

**Sargrove Electronics Ltd.**

*Synchronous motor timing unit*, with mains-operated electromagnetic clutch providing the facility for remote control and automatic resetting. Ranges: 1 minute variable to 40 minutes, 80 minutes or 120 minutes, with a high standard of setting and repetitive accuracy.
*Sequential electronic timers* with standard ranges of 0·1 second up to 4 minutes. Multi-channel electronic timing units can be made up to provide any desired combination of ranges, and where a longer period than is practicable with an electronic timer is required, this can be provided by combining a synchronous timer with the desired number of electronic timers. This very flexible combination provides accurate time setting over a range of up to 40 minutes.
*High-speed time recorders and counters* and photoelectric equipment are also produced by this concern.

* * *

**Sauter Controls Ltd.**

*24-hour dial time switches*, operated by hand-wound clockwork escapement (approximately 16 days reserve), motor-wound clockwork escapement (3 to 4 days reserve) or synchronous motor (no reserve). Solar dials, day selective device and a variety of contact arrangements and ratings are available.
*Contact clocks*, for change-over switching of double- and multi-tariff meters, control of remote switches, contactors, etc. Operated by hand-wound clockwork, motor-wound clockwork or synchronous motor. Daily or weekly dials available.
*Interval timer* for intervals from 1 second up to 6 hours. Normally-closed contacts, which open at the end of the timed period.
*Synchronous motor timer* with electromagnetic clutch and main and auxiliary contacts. Standard range 1·5 to 60 seconds, but can be obtained with ranges up to 60 hours.
*Interval timer* for switching a one, two- or three-pole a.c. circuit. Contact arrangements normally closed, change-over, or two separate circuits switched respectively On and Off.

* * *

**L. E. Simmonds Ltd.**

*Clockwork timing relay, type RTM.*
*Mercury tube timing relay, type RNT.*
*Thermal relay, type EPB.*
*Synchronous motor timer, type CB.*
*Electronic timer, type TE.*

* * *

**Smiths English Clock Systems**

*Synchronous motor time switches*, single circuit, twin circuit and single circuit with day selective device—will control up to twelve on/off timing operations every 24 hours.
*Clockwork hand-set minute timer*. For periods up to 60 minutes. Turning the pointer to the desired interval winds the spring, which then carries the pointer back to zero and rings a bell at the end of the timed period.
*Clockwork period timers* giving bell signal at end of timed period. For intervals from a few seconds up to 2 hours.
*Electrical* (*synchronous motor*) *second timers*. These instruments merely record the passage of time on dials calibrated 1 to 60, and do not operate any warning. One of the models has an additional small dial for recording minutes.
*Electrical* (*synchronous motor*) *minute timer* which can be set to time any process up to 60 minutes. Light-duty contacts close at the end of the timed period.

* * *

**South London Electrical Equipment Co. Ltd.**

*Non-synchronous electronic timers*. Ranges: 1·5 cycles up to 2 minutes, peak rating 30 amps, resetting time 10 milliseconds. The minimum setting time of the shorter period models can be reduced to 15 milliseconds if desired.
*Synchronous thyratron timers*. Ranges: 0–0·5 cycles variable, 0·5 and 1 cycle fixed times, or decade switching in ½-cycle steps to 5 cycles. Peak ratings from 20 to 80 amps. Resetting time 1 millisecond.
*Synchronous ignitron timers*. Ranges: 0–0·5 or 0–1 cycle variable, 0–8 cycles decade switching, and 0–100 cycles (decade switching to 8 cycles, variable 3–100 cycles). Peak rating 1,000 or 3,000 amps. Resetting time 10 milliseconds.
*Synchronous ignitron contactors* for use with any non-synchronous timer. Peak rating 1,000 or 3,000 amps.

Also available are special units for converting existing welding equipment to electronic control. Range 3 cycles to 2 seconds, with 25- or 75-amp contacts.

* * *

**Sunvic Controls Ltd.**

*Thermal time delay switches*, adjustable and non-adjustable. The adjustable type (ranges 15–90 seconds, 60–120 seconds and 90–210 seconds) can be supplied as a lock-on relay with a manual reset button; the non-adjustable type covers the range 1–6 minutes when used in conjunction with a suitable auxiliary magnetic relay, the combination providing immediate repeat facilities which are not obtainable with a thermal switch alone.

* * *

**Synchromatic Time Recording Co. Ltd.**

*Isgus hand-set interval timers*, with repeat facility. Single or double range models for periods up to 60 minutes.
*Junghaus high-accuracy time checkers*. These are, in effect, precision stop clocks incorporating a contact mechanism. Available with various control arrangements, these clocks have three dials and cover the ranges of 60 minutes in 0·1-second divisions or 12 minutes in 0·01-second divisions.
*Junghaus clockwork period timers and time switches*. A comprehensive range of hand-set and continuous timers covering timed periods from 1 minute up to 2 hours. The continuously running instruments operate for up to 36 hours with one winding.

* * *

**Venner Ltd.**

*Synchronous 20-amp. time switches*, available with solar dial or day selective device.
*Electrically wound time switches* (9-hour reserve), available with solar dial or day selective device.
*15-day hand-wound time switch, suitable for a.c. or d.c.* Day selective device available.
*Multi-circuit process control switches*, available in three main forms: synchronous without spring reserve, synchronous with 36-hour spring reserve and hand-wound (15 or 35 day). Up to six circuits can be controlled, and any switch can be supplied with solar dial and day selector which permits early switching or the complete omission of switching operations on the selected day or days.
*Mercury contact heavy-duty time switches*. The specially designed mercury cups fitted to these switches make them eminently suitable for switching loads from 10 amps d.c or 20 amps a.c. up to 50 amps.
*15-amp. and 30-amp. time switches*: synchronous motor with spring reserve, electrically wound with spring reserve, or hand wound. For off-peak water heating and specialised industrial applications.
*Synchronous motor process timers* with two-way contacts. Type PT3 is for use where, as a rule, different periods are required for successive operations. Type PT4 is for applications where the timed period is not often altered. Resetting takes place automatically at the end of each period. Ranges: Type PT3, 0–60 seconds up to 0–40 hours, type PT4, 3–60 seconds up to 2–40 hours.
*Hand-set spring-driven timers*. Ranges 0–90 seconds to 0–6 hours.

* * *

The following are among the British manufacturers of timing products whose activities in this field are confined to the manufacture of high-speed counting equipment which, though outside the scope of this survey, is nevertheless sometimes adapted for process timing: Labgear Ltd.; Marconi Instruments Ltd.; Panax Equipment Ltd.; and J. Langham Thompson Ltd.

Aish & Co. Ltd. and Radio-Aids Ltd. produce process timing equipment for specific applications only.

# NEW IDEAS IN DESIGN

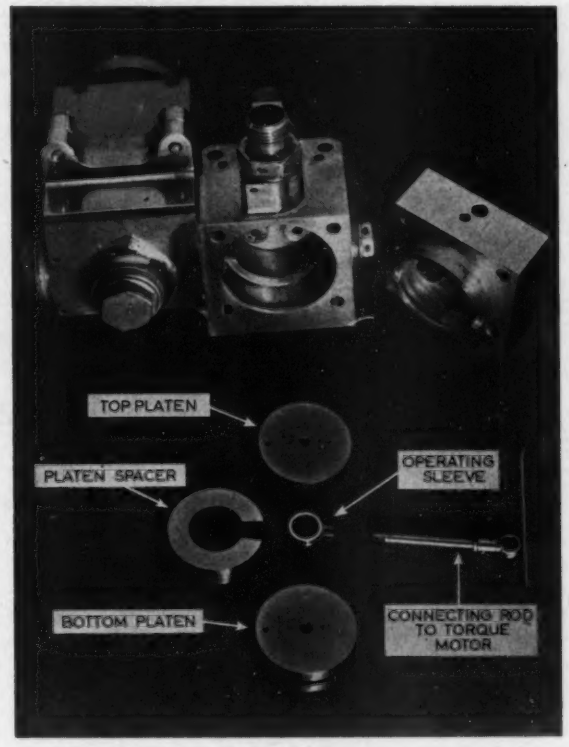
*Outstanding products in current manufacture*

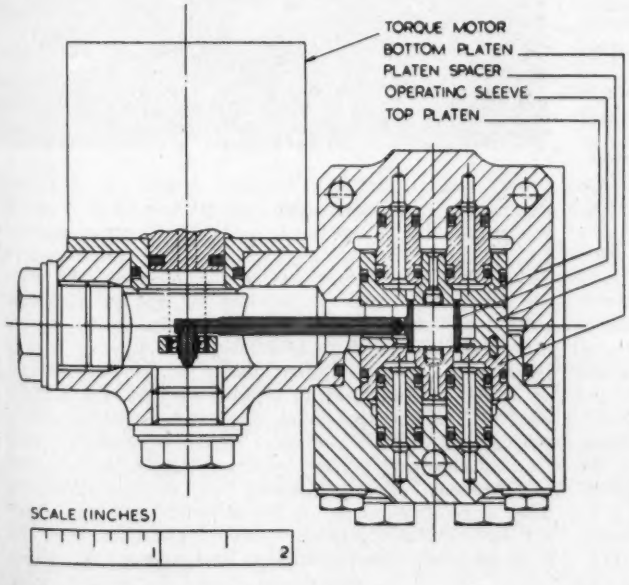
## Electro-hydraulic Servo Valve

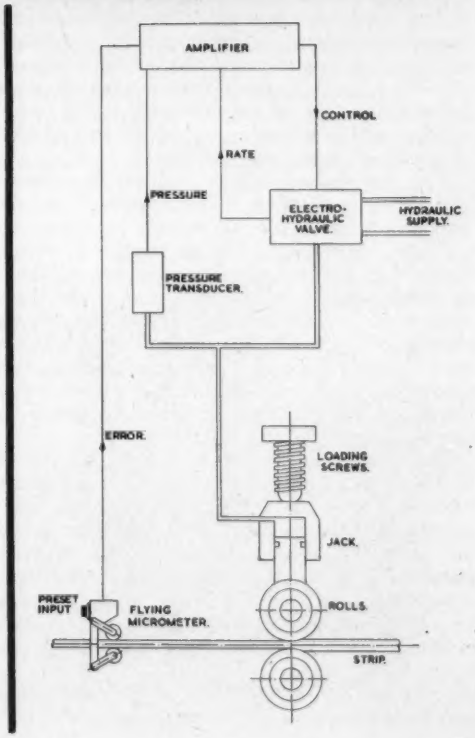
A NOTABLE exhibit at the recent Instruments, Electronics and Automation Exhibition at Olympia was a servo valve by the Hydraulics Division of Fairey Engineering Ltd. Originally developed for use in aircraft, the versions now available for industrial applications are of particular interest in that signals to the servo-valve of less than 1 milliamp can control 4 gal./min. through the valve at 4,000 p.s.i. A smaller version permits a flow of 1½ gal./min. In addition, two-stage versions are available for flow rates of 24 gal/min. and 61 gal./min. While the need for control devices of this nature, operating on signals of minute power coming from gyros and radar equipment, has been a necessity in high-speed aircraft for some years, the rapid growth of electronically-controlled machine tools and automatic control generally has greatly extended their field of application.

The various valves produced by Fairey, for use in conjunction with electronically-controlled systems, are all very similar in their basic design features, although in the aircraft types more attention has been paid to weight reduction. Essentially they consist of a hydraulic servo valve of the flat face type, operated by a crank on the spindle of an electro-mechanical transducer or torque motor. In torque motors of this type the armature takes up a given angular position when a differential current is maintained in the field windings. The angular position taken up is determined by the strength of a magnetic centring field in which the armature will rotate in order to balance the electro-magnetic field set up by the differential current. The torque output of the transducer is limited, particularly when deflected from its central position, with the result that the angular position of the armature is also affected to a great extent by any load against which the transducer must operate.

A study of the accompanying sectional drawing and photographs shows that the design is well adapted to production techniques. The balanced delivery valve consists basically of an operating sleeve, the surfaces of which are



accurately parallel and flat, sliding between two platens held a fixed distance apart by a platen spacer. The parts are pressure loaded together, the difference in height between the platen spacer and the operating sleeve determining the fluid film clearance which exists between the moving sleeve and the fixed platens. Special contour shaping arrangements are included which generate a positive restoring force if the sleeve, for any reason, tends to leave the centre of the fluid film space. To keep the operating forces at a consistently low level it is essential that a good standard of cleanliness be maintained with the low power transducers which must be used with these systems. To provide such filtration, the normal range of Fairey "Microfilters" is adequate.

The stability of servo control loops depends upon several factors, not the least of which is the "gain" of the system. The higher the "gain", the better the response and accuracy of control, but the greater will be the tendency to instability, particularly in the face of large inertia masses. With the low inertia masses of hydraulic actuators high gains can be used, and yet higher gains can be accepted if stabilising terms of one form or another can be built in. One means of increasing stability is to use internal "feedback loops", and Fairey servo valves are claimed to provide a ready means for the introduction of these stabilising loops. The torque motor has an a.c. inductive pick-off integrally built on, so that an electrical signal proportional to torque motor angular displacement is made available. Since torque motor displacement is also valve displacement, this signal gives an indication of the flow passing through the valve and therefore an indication of the velocity with which the associated actuator is moving. This signal can therefore be used as a conventional "velocity feedback system" term in the stabilisation of the servo system.

The line diagram illustrates the use of a Fairey electro-hydraulic control system, using electronic sensing and amplifying elements in conjunction with an electro-hydraulic valve in a B.I.S.R.A. experimental rolling mill at Sheffield. With little time for preparation, it is claimed that the system was set up and operated, and steel strip correct within $\pm 0{\cdot}0003$ in. produced automatically through the ingoing material varied as much as $\pm 0{\cdot}002$ in.

## Tool Changing and Positioning by Punched Tape

THE manufacture of large components for heavy engineering, such as condenser tube plates, the side members of machine tools, and gearboxes, have until now presented a considerable problem for the planning engineer. To produce very large drill jigs for components which are only required in ones and twos is clearly out of the question. While it is true that some large jig borers are capable of undertaking such work to close limits of accuracy, thus avoiding the cost of large jigs, their use means that a highly skilled operator must devote many hours to reading the drawing and carrying out the drilling and boring operations. In cases where such costly machines are not available, it is sometimes necessary to carry out lengthy marking-out operations in the old-fashioned way, the actual drilling being carried out on a large radial drill. The many drill changes which are often necessary and the many movements of the drill head which must be made require intense concentration on the part of the operator to avoid scrapping large components.

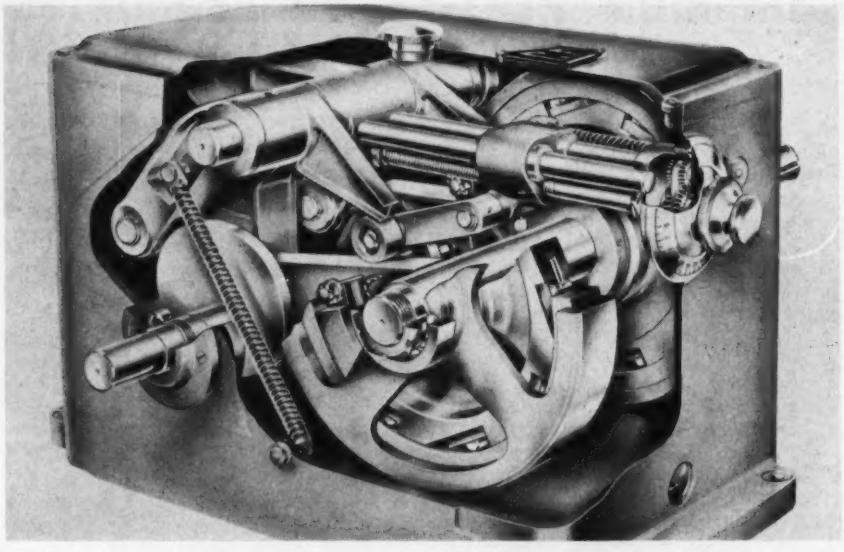
The Autonomic vertical co-ordinate drilling machine, the prototype of which was exhibited at the recent International Machine Tool Exhibition by James Archdale & Co. Ltd., represents a serious attempt to bring machine tool control and punched tape programming into this field. It makes possible the production of large components to close limits of accuracy and, in addition, greatly reduces the risk of errors by the operator. Once the machine has been programmed, all the drilling, reaming, tapping and spot-facing operations are carried out automatically, as are the movements of the table and the tool carriage from one position to the next.

The 6 ft. × 6 ft. vertical spindle machine illustrated carries, behind the circular tool guard, an indexing magazine of tools. This magazine is fitted with all the tools required for the drilling, reaming, etc., operations to be carried out. A tool-recognition device arrests this revolver or magazine when the appropriate tool is pointing vertically downwards, whereupon it is seized by a mechanically-controlled clamp which transfers it to the quill of the machine, where it is held by a hydraulically controlled collet.

Table and saddle positioning is by a diffraction grating system, and accuracy is claimed to be $\pm 0{\cdot}001$ in. The tape

reader and all controls, indicator lamps and dials are mounted on a console which houses the control electrical equipment and power supply units. Pendant controls are provided for use when setting up the machine under manual control. On the console are the push buttons used when the dimensional data are fed into the machine manually instead of from the tape. Spindle speeds, feeds and the type of cycle, i.e., drilling, spot-facing or tapping, are pre-set by dials for each of the fifteen tool numbers. Thus changes of speed and feed may be effected for any tool without alteration to the tape. When a particular tool number is demanded by the five-channel tape, the speed and feed which have been pre-set by the dials will be obtained automatically. There are fifteen rates of both speed and feed. A "Mirror-Image" switch is provided so that right- and left-handed components can be produced from the same push-button setting or tape information.

# A Positive Infinitely Variable Gearless Gearbox

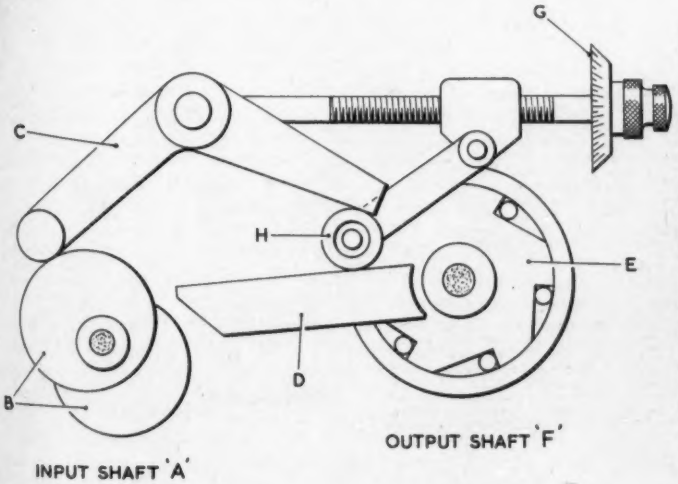


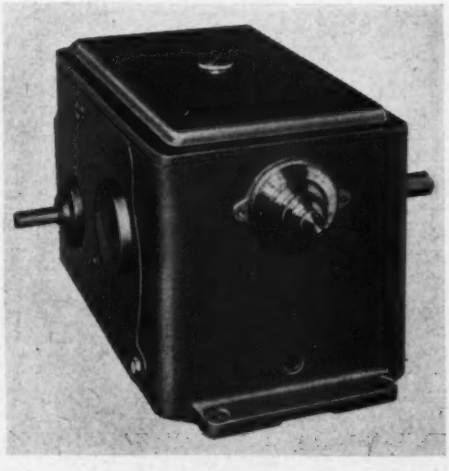
THE Contorq variable speed reduction unit, recently introduced by Fairbairn Ultro Ltd. of Leeds, is unique in that it is claimed to provide a completely positive drive of infinite variability. Although there already exist many belt and friction drives of great ingenuity and reliability, many of which have been described in this journal, the principle upon which the Contorq operates appears to be novel.

The diagrammatic and sectional views of the gearbox show the operating principle. Two single lobe cams (B) are secured to the input shaft, the cam lobes being fixed at 180 deg. to each other. Rotation of the cams imparts an oscillating movement to two levers (C) which, in turn, oscillate two levers (D), each of which is in contact with a roller-type free-wheel mechanism (E) attached to the output shaft (F). Adjustment of the control knob (G) moves roller (H) which is interposed between the levers (C) and (D), thereby varying the angular movement of the two levers (D) from zero to a maximum. The angular arrangement of the cam lobes imparts a continuous motion to the output shaft; i.e., as one free-wheel is driving, the other is returning to its starting position. The cams are designed to give constant angular velocity and overlap to eliminate loss of movement at the change from one free-wheel to the other.

The speed range is from an input shaft speed of 450 r.p.m., maximum output reduction rations from 9:1 to infinity giving output shaft speeds from 0-50 r.p.m. Speed changes may be effected when running or pre-set when stationary. The No. 25 unit has a constant torque output of 2,250 lb. in. over the entire speed range, smaller and larger units being shortly available. Control is by a graduated hand-wheel, but remote control by hand or servo can be accommodated if required. The mechanism is totally enclosed with a visual indicator, the overall dimensions of the unit being 26½ in. × 21¼ in. × 15¾ in. The weight, including 6 pints of oil, is 385 lb.

Our readers may be interested to know that the idea of using the sprag clutch type of free-wheel to produce an infinitely variable gear was suggested by one of our correspondents (H. Barrett, *E.M.&D.*, August-September, 1959, p. 453). The disadvantage of the rack and gear method he suggested was that it would have a sinusoidal output. The most notable feature of the Contorq is that, by careful attention to the geometry of the linkage and cam design, this has been avoided, the output being linear.



# HARD-CHROMIUM PLATING ON ALUMINIUM

TO increase the abrasion resistance of light-alloy cylinders which are being used in the motor industry, hard-chromium plating is applied to the surface of the cylinder bore. A new technique for the hard-chromium plating of light metal components without an intermediate layer has been evolved by Dr. Pál Csótán, head of mechanical engineering at the Research Institute of the Metal Industry, Budapest.* This process is said to ensure high-quality finish at an economy surpassing all methods known and used hitherto.

The aluminium alloy (11-14 per cent Si) cylinders, mounted on an appropriate tool (see Figs. 2 and 3), are degreased for 1-2 min. in a 10 per cent basic NaOH solution at 80 deg. C. temperature. Then, after being rinsed with water, they are pickled in a mordant composed of hydrogen fluoride and nitric acid in a pre-set molecular ratio at 15 deg. C. for 1-2 min. Special care has to be taken with the temperature, since a mordant warmer than 15 deg. C. would lead to not a bright silver-grey finish, but a blotchy, dark-grey, rough and eroded surface affording poor adherence for the chromium plating. Appropriate pickling renders the surface sufficiently resistant to the oxidising effect of air (especially in the wet state).

The plating proper is carried out in a solution of the usual composition in such a way that the density of the electrolysing current is increased to 2·27-2·91 amps per sq. in. in the first 5 min., to 2·91-4·20 amps per sq. in. during the second 5 min., and to 4·50-5·16 amps per sq. in. from the 10th min. onward. The temperature of the solution must be maintained at 60 $\pm$2 deg. C.

When the chromium layer is deposited, rinsing and a subsequent boiling in distilled water for 1-2 hr. follow, to remove particles occluded in the pores of the casting and the plating, and to relieve the internal stresses in the plating.

Since duration experiments have established the speed of deposition, the thickness of the plating layer can be controlled quite closely—a favourable circumstance from the practical point of view.

The main physical, mechanical and metallographical data for hard-chromium plating produced according to the above process are as follows:

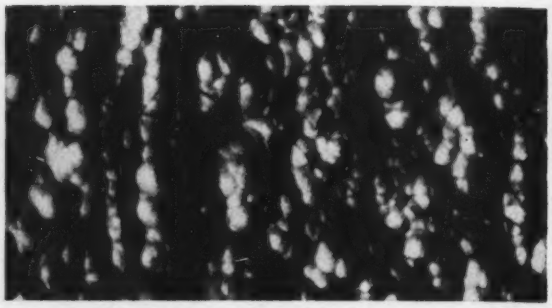


Fig. 1. Surface of hard-chromium plating processed under 5·16 amps per sq. in. current density (×50).

*Hardness*, measured by the Hanemann micro-hardness tester at 100 gm. load, on a ground cross-section: $H_v$ = 1,350 to 1,550 kg. mm.$^2$.

*Optimum thickness* of plating: 0·002-0·003 in.

*Optimum granularity* (see Fig. 1) of the plating can be obtained by appropriate adjustment of the current density within the above described range.

Before assembly in the engine, the chromium plating of the cylinder bore must be honed. The grease-retaining capacity of the plating of cylinders subjected to excessive stresses (as, for instance, in racing cars) may be enhanced by roughening the surface by anodic treatment in a 1 per cent nitric-acid solution under 1·94-2·58 amps per sq. in. density of the anode current.

Metallographic examinations of a cross-sectional specimen have established that the adherence of the plating to the basic metal is excellent, and that the chromium layer satisfactorily seals the micro-roughnesses of the surface.

The mechanical properties of the plating are determined by submitting the honed cylinders to "cold wear" tests (bench tests) in special abraders, and by prolonged service in motor-cycle engines.

Service tests after 50,000 miles showed that the amount of wear on the hard-chromium surface deposited by the above process did not exceed one-half of the permissible tolerance.

* Address—Femipari Kutato Intezet, Budapest XI, Fehervari u. 144, Hungary.

Data, diagrams and photograph by courtesy of the Information Service of the Hungarian Chamber of Commerce.

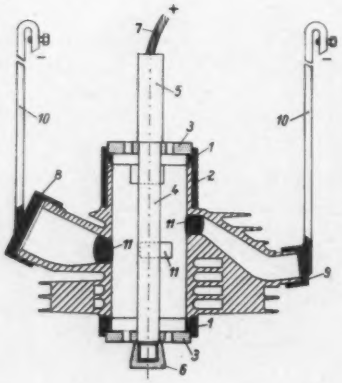


Fig. 2. Motor-cycle cylinder barrel mounted on a plating tool. KEY: 1—bore extension plate; 2—thrust plate; 3—perforated cap made of synthetic material; 4—lead auxiliary anode; 5—auxiliary anode insulating sleeve, made of polyvinylchloride; 6—anode connecting cable; 7—fixing nut made of synthetic material; 8—threaded contactor cap; 9—metal cap; 10—cathode leg with clamp, and 11—metal plug.

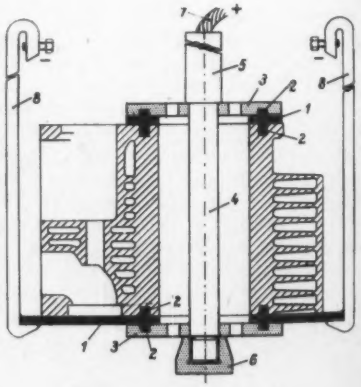


Fig. 3. Stationary motor cylinder barrel mounted on a plating tool. KEY: 1—thrust and extension plate; 2—locating rings; 3—perforated cap of synthetic material; 4—lead auxiliary anode; 5—auxiliary anode insulating sleeve of p.v.c.; 6—fixing nut of synthetic material; 7—anode connecting cable, and 8—cathode leg with clamp.

# OVERSEAS NEWSLETTER

*A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work*

### Weather Simulation Chambers

A series of low-temperature ovens in current use at the Convair Division of General Dynamics Corp., California, was designed to determine the degree of punishment which components and materials can withstand under simulated severe weather conditions. In addition to electrical heating facilities, the ovens contain salt spray accessories which, in a matter of hours, can duplicate conditions that cause metals to corrode in humid coastal areas over a period of years. Largest of these chambers is a 12 × 7½ × 8 ft. oven with black polythene walls and a painted aluminium floor. It produces temperatures up to 35°C. with two 16,000-watt banks of light and uses a 20 per cent salt spray to achieve high humidity in accordance with the settings of the control instruments.

In a normal 24-hour operating cycle, the large oven will use 50 gallons of salt solution in testing various items such as radar antennas, control boxes and ejection seats. Each component must naturally remain usable after the predetermined trials if its replicas are to be installed in Convair's aircraft. Smaller ovens are commonly used to test paint, plating and other finishes which are supposed to prevent corrosion in metal parts. Besides heat and humidity, air-agitated water and both ultra-violet and infra-red rays are used. Metal samples, coated in accordance with standard shop procedures, are inserted in the smaller ovens for different periods of time, and the degree of corrosion after removal determines the finish to be finally applied.

### Prestressed Concrete Pipes

The Sentab system incorporates a patented Swedish invention relating to the design of prestressed concrete pipes for conveying water or other fluids under pressure. Each section of pipe is prestressed both circumferentially and longitudinally by high-tensile steel wires, the circumferential reinforcement consisting of smooth surface wires, the longitudinal straight wires being crimped in order to obtain a perfect bond to the concrete. In contrast to many other types of prestressed pipes, the Sentab pipe is cast complete in one operation, which ensures that the walls are truly homogeneous and the entire cross-section is prestressed both longitudinally and circumferentially. This method of manufacture is said to ensure that no cracks will form, the reinforcement will be completely protected from corrosion, and the pipe will be completely impermeable from either inside or outside.

Pipes are normally made as socket types, the joint between consecutive lengths being made by means of a rubber gasket which is rolled in and compressed between spigot and socket at the same time as the spigot is pushed into the socket. At the spigot end, a protruding integral concrete ring transmits any transverse loads that may arise, thus protecting the rubber from excessive compression; it also stops the rubber ring from being forced out of place by high internal pressures. This type of joint is sufficiently flexible to allow for angular deviations between pipes, which enables a curved course to be followed without the use of specially shaped lengths of pipes.

### Molten Glass Prevents Scaling

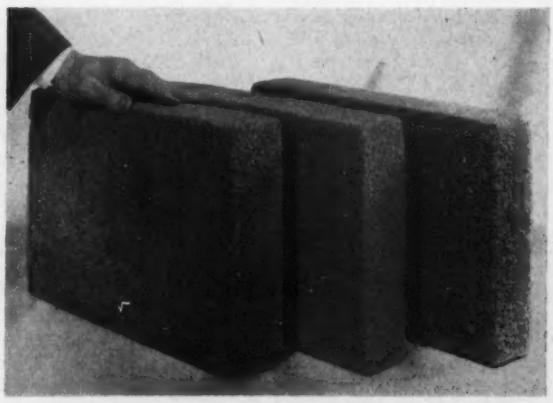
To protect the surface of steel billets against scaling during heat treatment, furnaces using special atmospheres are normally employed. Another method is to coat the billets with a thin film of molten glass. This protective coating can be applied to the billets as they pass through a revolving cylindrical vessel that contains the bath of molten glass. The billets are pushed along a trough in a refractory arch that is exposed constantly to the molten glass. As it collects in the trough of the arch, the glass drains back into the revolving vessel through lateral slots.

The refractory structure is assembled from bonded electric furnace mullite shaped especially for the purpose. The relatively pure aluminium silicate material combines several properties to resist the corrosive action of the molten glass and provide essential strength. Unlike mullite formed by calcinating kyanite, the electric furnace product contains no excess free silica that might be leached out by the glass to cause early failure of the refractory. Its dense body forestalls glass penetration that, upon repeated heatings and coolings, would cause it to disrupt.

This refractory shows virtually no deformation under a load of 25 p.s.i. at 1,500 deg. C., and in temperature resistance only may be safely used at above 1,650 deg. C. It will also withstand temperature fluctuations without spalling or cracking, due to its interlocking crystalline structure.

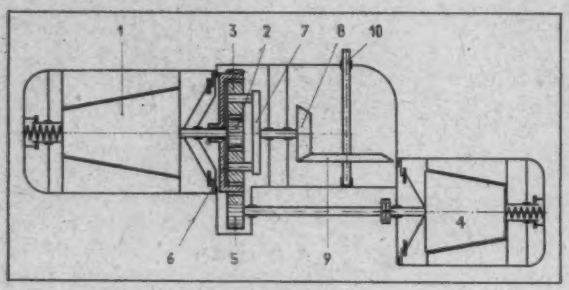
### Fused Quartz Foam

A new, low-loss, low-dielectric ceramic foam suitable for use at a temperature of 1,370°C. has been produced in the U.S.A. Designated Eccofoam Q, it has a unicellular foam structure of essentially pure silicon dioxide, the weight being approximately 12 lb./cu. ft. At microwave frequencies the dielectric constant is 1·2, the dissipation factor being below 0·001. With these properties it is particularly useful in microwave devices such as windows, radomes and antennas. Eccofoam Q can be machined by abrasive cutting and grinding, and can be bonded to itself or to other ceramic material.



### Variable Speed Drive

It is frequently desirable to drive underground conveyors at various speeds without change in torque. The Demag ABV gear drive combines the economy of electrical drives with an added flexibility. This gear drive mainly consists of a planetary gearing in which both the sun pinion and the planet carrier are each driven by a motor. The sun pinion can be stopped by switching off the motor and applying a brake at the same time as the planet carrier motor is switched on. Both motors can also be switched on together, their contributions to the speed of the output shaft being added to one another. In addition, it is possible to have the smaller motor rotate in the opposite direction, so that its contribution diminishes the speed of the




other motor. In the diagrammatic sketch, motor (1) drives the planet wheels (3) via the sun pinion (2). Motor (4) has been switched off and braked, so that pinion (5) holds the rim (6). Consequently, motor (1) turns the planet carrier (7) which, in turn, drives the output shaft (10) via the bevel wheels (8) and (9). If motor (4) is switched on for rotation in the same direction, it increases the speed of the output shaft (10). If motor (4) is switched on for rotation in the opposite direction, the speed of the output shaft is reduced accordingly. If motor (1) is switched off, it is locked by the brake, the sun pinion is arrested, and the rotational speed on the output shaft end is determined by the rotational speed of motor (4). If the motors and transmission gears are suitably designed, it is possible to obtain any required speed.

An advantage with this type of drive is that when the unit is switched on, a start is made with the lowest speed before the maximum speed is reached via the intermediate two speeds. This reduces the starting load on the motors to a fraction of that of a single-motor drive with a corresponding output. It should be noted that mechanical braking is only partially effected, as in switching off by steps part of the energy is dissipated electrically, so that the mechanical brakes are subject to relatively little stress or wear.

### Circulatory Disturbances of Air Brakes

A recent German publication has likened the symptoms of malfunction of air brakes to those of malfunction of the human body, for the purpose of instructing drivers and mechanics. Since the compressor may well be regarded as the heart of a compressed air braking installation, reference is made to a certain "weakness of the heart" if the air supply is insufficient. The fault can be rectified very easily at this stage, so that the illness does not become chronic, and serious functional disturbances are avoided.

Breathlessness is likened to excessively slow or insufficient air supply, and is usually caused either by a blockage in the air filter or by a slipping or otherwise faulty belt. If these two parts are in good condition, it may be assumed that "arteriosclerosis" is present in the pressure lines, leading usually to the compressor being overloaded.

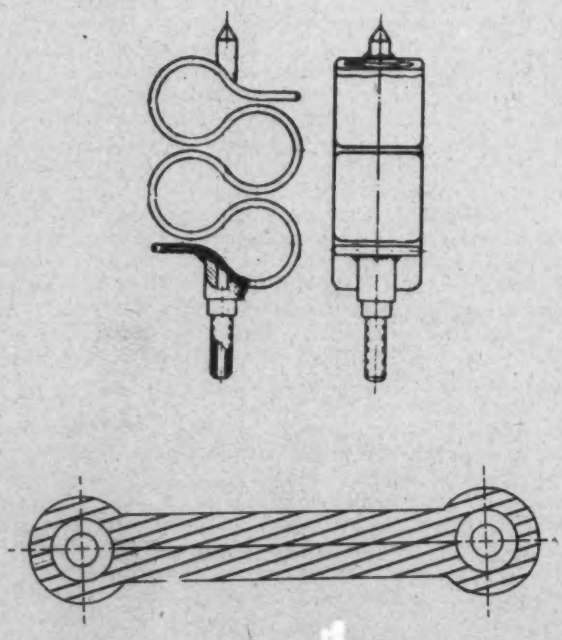
Regulatory disturbances are usually caused by dirty pressure governors being no longer capable of digesting the compressed air supplied.

Brake valves should be *sensitive*, i.e., respond easily, and should be examined at certain intervals. It is also expedient to regularly replace the inlet and outlet valves, since their seats will probably become worn. Brake cylinders should be adjusted to as short a stroke as possible (about one-third of the usable stroke) in order to reduce the air consumption, which might otherwise lead to *exhaustion* of the air supply.

If the state of health of the air brake is examined, and rectified where necessary, disturbances will be prevented which might endanger the running safety of the vehicle.

### S-Shaped Instrument Springs

The research section of the Institute of Heat Engineering Instrumentation in Russia has developed a new type of tubular spring for pressure gauges and manometric thermometers. It consists of an even number of uniform S-shaped curves made from flat profile tubing. With a variation of the pressure inside the S-spring, the free ends of two adjacent S-sections perform a movement which is identical in magnitude but different in direction, at the same angle relative to the central axis of the spring. The result is that the overall displacement of the free end of the S-spring is linear along the central axis and similar to the working displacement of bellows diaphragms. These springs are said to be particularly useful when measuring pressures in excess of approximately 250 p.s.i., when bellows and diaphragms are difficult or impossible to employ. In the case of fluid thermometers, S-springs are said to be more efficient than bellows since the former possess a smaller internal volume, and the measuring error due to temperature of the air surrounding an elastic sensitive element and the connecting capillary of a fluid thermometer is less. In an S-spring used for manometric thermometers, each of the twin channels contains Invar (iron-nickel alloy) wire. With a rise in the temperature, the expansion of the annular space thus formed compensates to a high degree for the increase in the volume of the fluid.



(Top) S-shaped tubular springs for instruments; (bottom) enlarged sectional view of a tubular spring containing Invar wire.

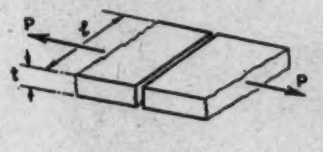
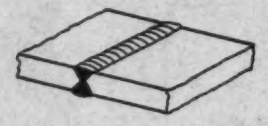
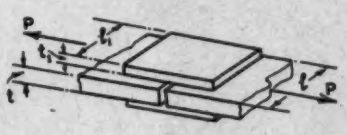
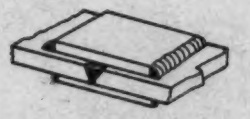
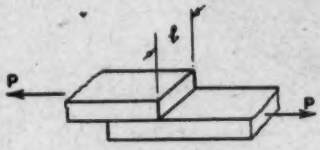
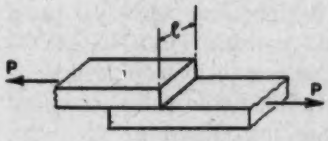
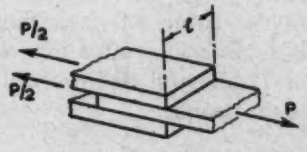
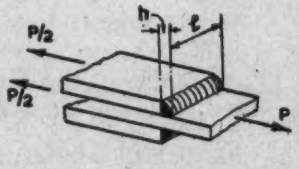
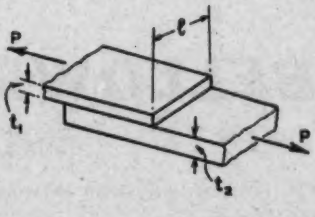
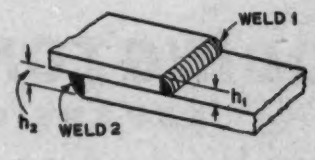
# WELD STRESSES FOR COMMONLY USED ATTACHMENTS

**Engineering Materials and Design**
## DATA SHEET No. 44

*Values for Stress Concentration Factors * for Fatigue Design*

| Type of joint | Factor K | Type of joint | Factor K |
|---|---|---|---|
| At edge of reinforced butt weld | 1·2 | T-butt joint with sharp corners | 2·0 |
| At toe of transverse fillet weld | 1·5 | Transverse bead on plate | 1·3 |
| At end of parallel fillet weld | 2·7 | Transverse fillet welded cover plates | 3·0 |

* *Multiples of calculated static stress.*

| Method of Loading | Type of Joint | Stress in Weld |
|---|---|---|
|  |  | $f = \frac{P}{tl}$ |
|  |  | In fillet: $f = \frac{\frac{1}{2}P}{0{\cdot}707\ t_1\ l_1}$<br>In butt: $f = \frac{P}{(2t_1\ l_1 + tl)}$ |
|  | | f (max. principal stress) $= \frac{4{\cdot}24\ P}{tl}$<br>where t = plate thickness |
|  | | f (max. principal stress) $= \frac{1{\cdot}618\ P}{tl}$<br>where t = plate thickness |
|  |  | $f = \frac{0{\cdot}707\ P}{tl}$<br>where t = h = plate thickness |
|  |  | $f_1$ (Stress in weld 1) $= \frac{1{\cdot}414\ P\ t_1}{l h_1\ (t_1 + t_2)}$<br>$f_2$ (Stress in weld 2) $= \frac{1{\cdot}414\ P\ t_2}{l h_2\ (t_1 + t_2)}$<br>where $t_1$ and $t_2$ are equal<br>$f_1 = f_2 = \frac{1{\cdot}414\ P}{l\ (t_1 + t_2)}$<br>($t_1$ and $t_2$ are plate thicknesses, and $h_1$ and $h_2$ are weld depths) |

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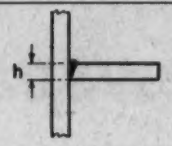
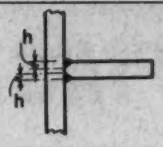
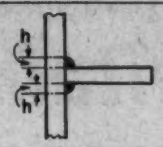
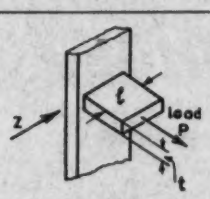
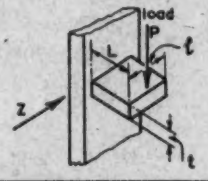
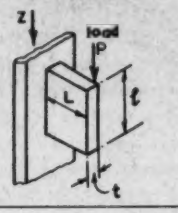
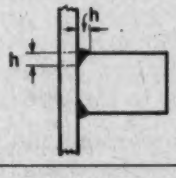
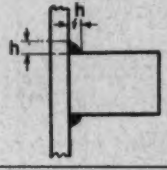
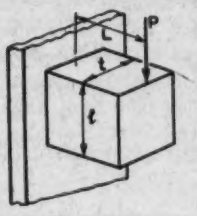
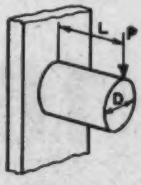
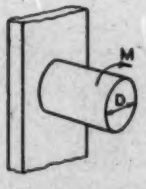
# WELD STRESSES FOR COMMONLY USED ATTACHMENTS (Cont.)

| Alternative Welds / Type of Loading | View on arrow Z (h = weld dimension) | | |
|---|---|---|---|
| |  |  |  |
|  | $f = \frac{P}{lh}$ | $f = \frac{0.5\,P}{lh}$ | $f = \frac{0.707\,P}{lh}$ |
|  | Bending: $f = \frac{6PL}{lh^2}$<br>Shear*: $f = \frac{3P}{2lh}$ (at mid-depth) | Bending:<br>$f = \frac{3PLt}{h(3t^2 - 6lh + 4h^2)}$<br>Shear: $f = \frac{3P}{4lh}$ | Bending: $f = \frac{1{\cdot}414PL}{lth}$<br>f max. $= \frac{0{\cdot}707P}{lh}\sqrt{1 + \frac{4l^2}{t^2}}$<br>(max. bending and shear when h is small compared with t) |
|  | Bending: $f = \frac{6PL}{l^2h}$<br>Shear*: $f = \frac{3P}{2lh}$ (at mid-depth) | Bending: $f = \frac{3PL}{l^2h}$<br>Shear: $f = \frac{3P}{4lh}$ (at mid-depth) | Bending: $f = \frac{4{\cdot}24PL}{l^2h}$<br>Shear:<br>$f = \frac{1{\cdot}06P}{lh}$ (at mid-depth) |

| Alternative Welds / Type of Loading | | |
|---|---|---|
| |  |  |
|  | $f = \frac{6PLl}{l^3\,t - (l - 2h)^3\,(t - 2h)}$<br>If h is small compared to *l*, higher powers of t may be neglected and:<br>$f = \frac{3PL}{lh\,(3t + l)}$ | $f = \frac{4{\cdot}24PL}{lh\,(3t + l)}$ |
|  | Bending: $f = \frac{10{\cdot}2PLD}{D^4 - (D - 2h)^4}$<br>If ratio h/D is small<br>$f \simeq \frac{1{\cdot}27PL}{D^2h}$ | Bending: $f = \frac{10{\cdot}2PL\,(D + 1{\cdot}414h)}{(D + 1{\cdot}414\,h)^4 - D^4}$<br>If ratio h/D is small<br>$f \simeq \frac{1{\cdot}76PL}{h\,(D + 0{\cdot}707h)^2}$ |
|  | Shear: $f = \frac{5{\cdot}1\,M\,(D - h)}{D - (D - h)}$<br>If ratio h/D is small<br>$f \simeq \frac{0{\cdot}9\,M}{D^4\,(D - h)^4}$ | Shear: $f = \frac{5{\cdot}1\,M\,(d + 1{\cdot}414\,h)}{(d + 1{\cdot}414\,h)^4 + d^4}$<br>If ratio h/D is small<br>$f \simeq \frac{0{\cdot}9\,M}{hD^3}$<br>Assuming that the torque M is resisted by a shear force acting in the weld throat |

Maximum stress from bending occurs at extreme upper edge of weld. Shear stress at this point is zero. *Indicates where the maximum shear stress occurs at mid-depth and is 1½ times the mean shear stress.

*Data by courtesy of H. B. Merriman, M. I. Mech. E., and the Institute of Welding.*

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# STRENGTH OF PLASTICS

**Engineering Materials and Design**
**DATA SHEET No. 45**

The information that the engineer or designer requires about plastics is not simply a series of values based on the results of arbitrary tests, but information that will give him a full understanding of the behaviour of plastics under stress and a standard method of comparing one plastic with another.

When stressed beyond its limits, a plastic will fail in one of two fashions—a brittle fashion or a tough fashion. Each of these types of failure can be characterised by the shape of the stress/strain curve plotted when the material is tested (see graphs 1 and 2).

The major factors affecting the brittle tensile strength of plastics (but not the yield strength) are molecular weight, orientation, void content, surface condition, degree of crystallinity in mainly amorphous polymers, and size of crystallites in mainly crystalline polymers. Yield strength is appreciably affected by temperature and rate of test (which have only a very small effect on brittle tensile strength), and by the degree of crystallinity of mainly crystalline polymers. The point at which transition from tough failure to brittle failure occurs is, of course, the point at which the yield strength of the material equals its brittle tensile strength, and the transition point is therefore affected by all the variables which affect either the brittle tensile strength or the yield strength.

A further very important factor affecting the position of the tough/brittle transition in any material is the presence of notches, whether external (either deliberately or accidentally introduced) or internal (caused by voids, bubbles, spherulites or other inhomogeneity).

If the ratio of the brittle tensile strength to the yield strength of a material is not much greater than unity, that material is likely to be notch-sensitive, since the presence of a notch will lower the brittle tensile strength to well below the yield strength; conversely, a material of which the brittle tensile strength is several times as high as its yield strength will not be notch sensitive, because its brittle tensile strength, though effectively reduced by the presence of the notch, will remain higher than the yield strength.

Table 2 shows some results obtained from a series of tests on a number of plastics. The values quoted apply, of course, only to the particular samples tested, and should not be taken as definitive for the class of material as a whole. However, they give some indication of the order of strength of the materials concerned, and provide a means of making an approximate comparison between them.

---

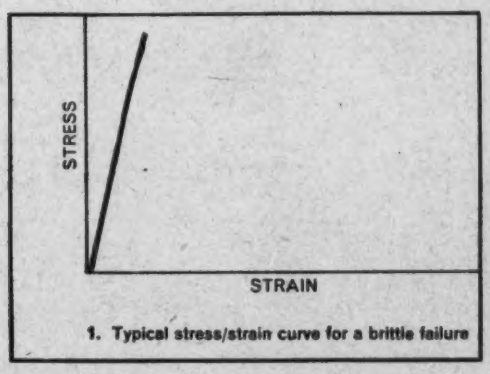
*Data by P. I. Vincent, M.A. (I.C.I. Plastics Research).*

TABLE 1. Tests to determine characteristics

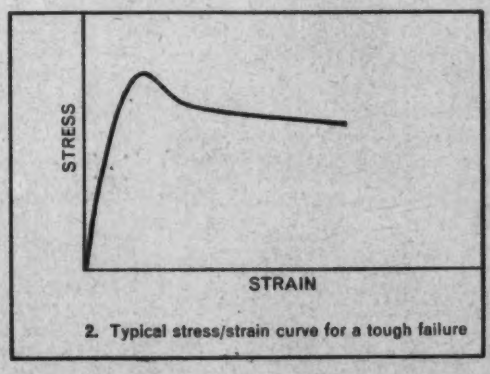
| Class of Material | Quantity measured in | | |
|---|---|---|---|
| | Tensile Test at 20°C. and 0·3 in./sec. Elongation | Falling Weight Tensile Impact Test | Tensile Test after Suspension of Specimen in Liquid Nitrogen |
| Brittle... ... ... | Brittle tensile strength<br>Energy to brittle break | — | — |
| Shock-brittle ... | Yield strength<br>Energy to tough break | Critical velocity for tough/brittle transition<br>Energy to break | Brittle tensile strength<br>Energy to brittle break |
| Tough ... ... | Yield strength<br>Energy to tough break | Energy to tough break | Brittle tensile strength<br>Energy to brittle break |

TABLE 2. Test results on various plastics

| Material | Tensile Test at 20°C. 0·3 in./sec. Elongation | | | Falling Weight Tensile Impact Test at 20°C. | | Tensile Test at −196°C | Ratio of Tensile Strength to Yield Strength |
|---|---|---|---|---|---|---|---|
| | Brittle Tensile Strength (p.s.i. $\times 10^{-3}$) | Yield Strength (p.s.i. $\times 10^{-3}$) | Energy to Break (ft. lb./cu. in.) | Energy to Break (ft. lb./cu. in.) | Speed (in./sec.) | Brittle Tensile Strength (p.s.i. $\times 10^{-3}$) | |
| Polythene (density 0·919 m.f.i. 2) | — | 1·7 | 350 | 211 | 230 | 13·5 | 7·8 |
| Polythene (density 0·95 m.f.i. 0·6) | — | 4·5 | 135 | 122 | 280 | 15·1 ±0·6 | 3·4 |
| Polypropylene | — | 5·9 | 50–300 | 47±4·7 | 240 | 12·0 +1·7 | 2·0 |
| p.t.f.e. (granular, 51% crystallinity) | — | 2·5 | 447 | 275 | 230 | 11·7 | 4·7 |
| p.v.c. (K65) | — | 10·7 | 264±20 | 290 | 250 | 20·8 ±2·8 | 1·9 |
| Cast acrylic | 9–11 | — | 10 | 10 | — | 11·5 ±0·7 | — |
| Granular acrylic | 9·0 ±0·9 | — | 10 | 10 | — | — | — |
| GP polystyrene | 8·8 | — | 4 | — | — | — | — |
| Toughened polystyrene | — | 5·6 | 20 | 32 | 80 | 8·0 ±0·7 | 1·4 |
| ABS copolymer | — | 6·5 | 175±50 | 206±9 | 140 | 12·2-13·7 | About 2 |




1. Typical stress/strain curve for a brittle failure




2. Typical stress/strain curve for a tough failure

# New Books

**The Sequestration of Metals—Theoretical Considerations and Practical Applications.** *By Robert L. Smith.* (*Chapman & Hall—42s.*)

In spite of the considerable importance attained by sequestering agents in industry and analysis, there has previously been no book dealing solely with this subject in all its aspects. It is evident from the table of contents of this work that the author has attempted to cover a very wide field and, in the opinion of the reviewer, not wholly satisfactorily, particularly as regards the first section of the book, dealing with theoretical principles. For example, chapter two, entitled "Valency and Basicity", deals with the elementary theory of valency, including qualitative discussion of the various inductive and mesomeric effects on the influence of molecular structure on basicity. If the reader were already familiar with this basic valency theory, then most of this chapter would be unnecessary. On the other hand, if he were not, the method of presentation would lead to confusion, which would be increased by errors in the tabulated material used and by doubtful statements in the text.

The discussion (chapter three) of the chelate ring and the influence of ligand and metal on the strength of bond is not as clear as could be desired. Again the author quotes a theory which, in the reviewer's opinion, adds nothing to the general argument and, indeed, is incorrect. Thus, the theoretical explanation for the greater stability of chelates as compared with simple co-ordination compounds (p. 32) rests on the statement that, subsequent to the formation of one link with the metal ion, the second ligand is rendered *more* basic. In fact, the exact reverse is true.

The two chapters on chemical and physical properties of sequestering agents and general considerations in their application are perhaps the most valuable part of the book for the general reader. The last half of the book, dealing with applications of sequestering agents according to industry and use, is also of value, but mainly as a guide to the literature because the field covered is so wide that inevitably many sections consist of little more than a catalogue of applications. The bibliography on applications is extensive and more than 1,000 references are given, as well as a bibliography of analytical methods using E.D.T.A.

*C. A. Parker*

**Mechanical Design of Laboratory Apparatus.** *By H. J. J. Braddick.* (*Chapman & Hall—6s.*)

This booklet is one of the monographs issued on behalf of the Institute of Physics for the student reading for the Higher National. The contents are clearly presented and cover the fundamental design principles of gears, slides, flexible couplings and other mechanisms found in laboratory apparatus.

**A.S.T.M. Standards on Metal Powders and Metal Powder Products (with related information).** (*American Society for Testing Materials—$2.25.*)

Compiled to the same high standards as previous specifications already issued, a concise and convenient method is laid down in this publication for the accurate and efficient testing of metal powders and products.

Tentative tables are given of chemical requirements suitable for producing sintered oil impregnated bearings, parts for structural use made from sintered iron-copper, bronze, brass, copper-infiltrated iron, and low, medium and high-density iron. A tentative specification is also included of a high-density tungsten-nickel-copper alloy suitable for machining. The testing procedures for density, porosity, hardness, etc., are also very clearly dealt with.

Small though this book is, it gives a wealth of information for those associated with the production, testing, quality control and uses of metal powder products. It is well illustrated and written, giving a very clear easy-to-follow history of these materials. An appendix is included, giving a cross-index of other well-known American Standards on this subject, together with their source.

*F. Smith*

**Soldering Manual.** (*American Welding Society—$5.*)

The data contained in this manual are presented in a clear and concise manner which will do much to dispel misunderstandings associated with the art of soldering. Early chapters supply the itemised composition of solders, simplifying the selection of the correct solder for a specific application. Non-corrosive, intermediate and corrosive fluxes and their chemical composition and effects on various metals, together with an illustrated exposition of the theory of flux action, are dealt with fully.

The major part of this work is devoted to the complete and detailed technique of cleaning, pre-coating and soldering of individual metals. Solutions are provided for the problems encountered when soldering the difficult nickel and chromium alloys. The soldering of precious metals and printed circuits is discussed shortly but pertinently, whilst the concluding chapter is informative regarding precautions against sources of injury encountered during soldering processes.

*A. H. Roach*

**The Effects of Nuclear Radiation on Men and Materials.** *By T. Helvey.* (*Chapman & Hall—15s.*)

The mobile application of nuclear energy presents many technological and biological problems. In this book some basic principles and pertinent data have been collected, including various radiation shield configurations.

**Introduction to Rubber Technology.** *Edited by Maurice Morton.* (*Reinhold, Chapman & Hall—80s.*)

Sponsored by the division of rubber chemistry of the American Chemical Society, and intended as an elementary text-book on rubber technology, this book is an edited compilation of selected lectures from courses organised by the various regional groups of the A.C.S.

The emphasis throughout is on materials and compounding, the coverage of these important aspects being comprehensive. Its 550 pages include chapters on natural, and eight types of synthetic, rubber in addition to others covering the major compounding ingredients, together with an excellent introductory chapter by B. S. Garvey, Jr.

As is probably inevitable in a collection of papers by different authors, there is some variation in both standard and level from chapter to chapter. The sponsors have, however, achieved their aim in providing a volume which will be of substantial value to students of rubber technology, both as an introduction to the subject and as a work of reference over several years of study.

As one expects of a Reinhold publication, the production and presentation are excellent and the text is well illustrated by many informative diagrams.

*J. A. Stephens*

**OTHER BOOKS RECEIVED**

**British Standard 3228, Part 2: 1960.** (*Part 1, procedures for obtaining properties of steel at elevated temperatures; Part 2, rupture strength—3s.*)

**The Operation of a Company Standards Department.** (*P.D. 3542 British Standards Institution—3s.*)

**British Technical Book List.** (*Seventh edition by The Publishers Circular Ltd.—2s. 6d.*)

**Joints in Aluminium and Aluminium Alloy Busbars.** *By A. P. Singh.* (*E.R.A. Publication Z/T118—12s. 6d.*)

**The Resistance of Sheet Insulation to Surface Discharges.** *By J. H. Mason.* (*E.R.A. Publication L/T 379—15s.*)

**Some Methods of Calculating the Bending Strength of Plywood.** *By I. D. G. Lee.* (*T.D.A. Publication—3s. 6d.*)

**Fabrication Manual for Connectored Assemblies.** (*T.D.A. Publication—3s. 6d.*)

**Production Standards for Structural Glued Laminated Timber.** (*T.D.A. Publication—3s. 6d.*)

**Year Book and Technical Guide.** (*Association of Supervising Electrical Engineers—5s.*)

# WHAT'S NEW IN MATERIALS & COMPONENTS

## Ion Exchanged Resin

The first of a new series of ion exchanged resins to become commercially available is Amberlite 200, which is a high capacity, strongly acidic cation exchange resin developed by Rohm & Haas Co., Philadelphia. It is a sulphonated styrenedivinylbenzene copolymer, as are the standard resins, but it is claimed that exceptional chemical and physical stability has been built into its polymeric structure by major changes in resin synthesis. The new resin is particularly recommended for use in treating water supplies that cause conventional resins to de-crosslink; for the "hot lime-zeolite" process; for rejuvenation of plating solutions; for sugar processing, and in mixed-bed (Monobed) deionization. It is also suggested for use in the treatment of highly aggressive solutions or where high operating temperatures are involved. Charles Lennig & Co. (Great Britain) Ltd., 26-28 Bedford Row, London, W.C.1.

**EMD 3606** for further information

## Welding Tape

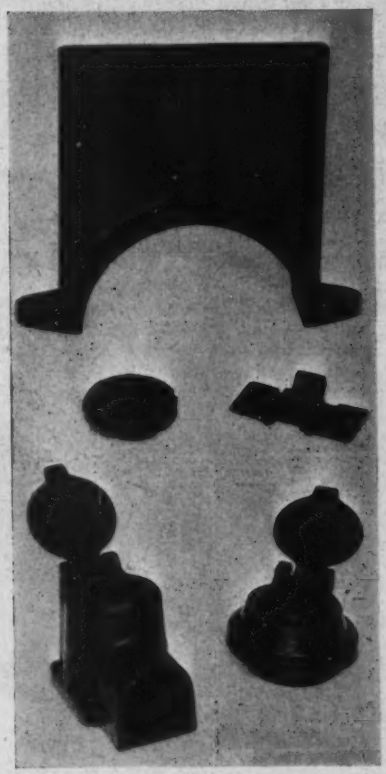
Thermobande is a newly-developed resistance tape with adhesive paper support which can be used for welding thermoplastic sheets and foils. Originally developed in France, it is now available in this country. The tape consists of a nickel alloy resistance heater attached to an adhesive paper which can be easily fixed to almost any surface. It is available in a range of sizes and in two basic types, SF (single face) for general applications and DF (double face) in which two metal strips are used, one on each side of

the paper. The latter is recommended for welding thicker plastic sheets (¼ in. and over) and permits greater current input.

The tape is used by fixing it along the weld line and connecting the ends of the tape to a low-voltage source such as a battery or mains transformer. Materials which can be welded are said to include polyethylene, polypropylene, p.v.c., polystyrene and polyamides. Delbag Air Filters Ltd., Arundel Road, Trading Estate, Uxbridge, Middlesex.

**EMD 3607** for further information

## Gravity-cast Plastic Castings



A number of different castings have been made recently in plastic, using inexpensive moulds. It is claimed that, in most cases, the casting can be produced to finished dimensions, machining being thus unnecessary. Ultimate tensile strengths of 8,000 p.s.i. and temperature resistance up to 204 deg. C. are said to have been achieved. Research is still proceeding, but castings up to 3 ft. long have already been produced, and have shown considerable savings over the cost of machined non-ferrous castings. The specialised technique which has been developed has proved that quantities of as few as fifty off are practical, due to the low cost of the moulding equipment. ManMil Plastics Ltd., Castle Street, Stalybridge, Cheshire.

**EMD 3608** for further information

## Adhesive Polyester Film

Heat-activated Melinex is a polyester film backed with a heat-sensitive adhesive which softens in the temperature range 77-133 deg. C. When laminated at these temperatures, the material is said to give exceptional clarity and protection from dirt, grease and chemicals. It is also claimed that the abrasive and ageing properties are extremely good. The film is also available with a normal self-adhesive backing and this eliminates the need for a heating process. Permacel Tapes Ltd., 260 Bath Road, Slough, Bucks.

**EMD 3609** for further information

## Curing Agent

A new room temperature curing agent, Epikure RTL, has been added to the range of curing agents for liquid Epikote resins, which are used in the engineering industry. It has been specially developed for use with Epikote's 828 and 815 in the production of glass fibre reinforced laminates, which have good mechanical and chemical-resistant properties. A feature of the new curing agent is its low viscosity (about 2 poises at 23 deg. C.), a property which gives improved handling characteristics. Shell Chemical Co. Ltd., 15-17 Gt. Marlborough Street, London, W.1.

**EMD 3610** for further information

## Coal Tar/Epoxy Coating

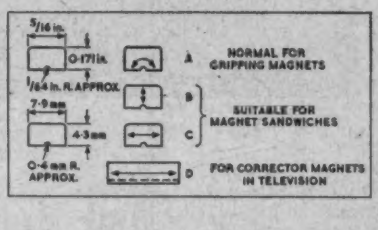
A protective coating, Tretol coal tar/epoxy 177, has recently been developed which in two coats attains a remarkable film thickness of 0·02 in., equivalent to some 15 to 20 coats of normal paint, at a fraction of the cost. It is claimed to have outstanding resistance to all forms of attack by acids, alkalis, sea-water, oil, sewage and brine to an extent not previously possible by brushed application. Excellent adhesion is obtained without priming on metals and concrete. It is designed to preserve plant, pipework, tanks, coke-oven equipment, dock and harbour installations, etc., from chemical attack. Tretol Ltd., The Hyde, London, N.W.9.

**EMD 3611** for further information

## Plastic Magnetic Strip

Eclipse magnetic strip is a permanent magnetic material, rather like cab-tyre cable in appearance. It is mechanically different from other permanent magnet materials in that it is semi-flexible and soft, so that it can be easily cut with a knife or drilled. Magnetically, it is said to have low remanence and energy content but very high coercivity, and electrically it is said to be a good insulator.

It can be extruded in strips (in the near future it will be available in sheets) and can be supplied in continuous lengths or as individual magnets. It is said to be almost impossible to demagnetise this material by mal-treatment. Suggested applications include door closures, lids and panels of equipment, swarf collection in engines or gearbox sumps, and in con-



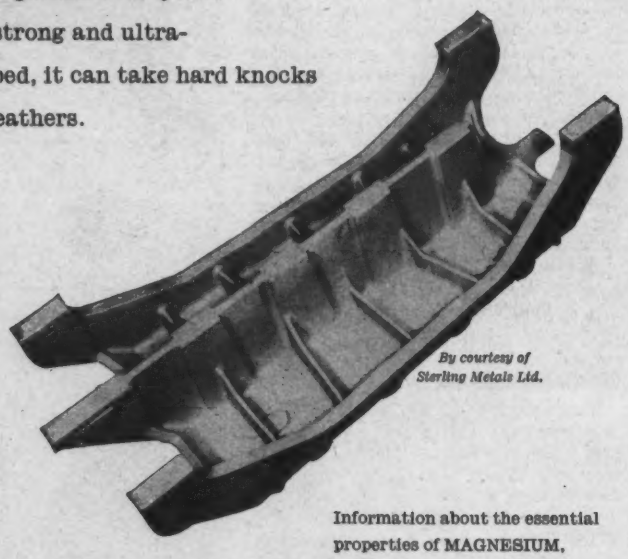

veyor systems for small ferrous components. James Neill & Co. (Sheffield) Ltd., Napier Street, Sheffield, 11.

**EMD 3612** for further information

EMD 3516 for further information

Because the Rotaped half-track unit is shod with track links gravity die cast in lightweight magnesium, it can work without bogging down over soil too soft for a wheeled tractor. By halving and spreading the weight, the links also minimize soil compaction. The Rotaped operates in all conditions over every type of land. Magnesium alloy was chosen because it is strong and ultra-light. Like the Rotaped, it can take hard knocks and rough it in all weathers.

# MAGNESIUM SPEEDS THE PLOUGH



*By courtesy of Sterling Metals Ltd.*

Information about the essential properties of MAGNESIUM, and advice on how this metal can best be converted into popular products, is always freely available from MEL—pioneers and sole producers of Magnesium in Great Britain.

## make more of magnesium

**Magnesium Elektron Limited**

Clifton Junction Manchester Swinton 2511
London Office: 5 Charles II Street St. James's SW1 Trafalgar 1646
Magnesium Elektron, Inc., New York 20, USA

## Glass Fibre Tubes and Ductings

A patented method of fabricating glass fibre reinforced polyester pipes and ductings is now being carried out in this country. This is said to enable the production of pipes with bore dimensions from 1¼ in. to 20 in., in lengths up to 40 ft., without joints. The wall thickness of the material can be varied between $\frac{1}{64}$ and $\frac{1}{16}$ in.

These tubes are claimed to provide an extremely high strength/weight ratio and together with their very good chemical resistance properties, and lengths available, constitute a completely new aspect of the ducting field. By variation of

weaves of glass fabric, i.e., square weave, satin weave, unilateral weave, pipes can be designed to give major strength characteristics to suit specific applications. In addition, by incorporating synthetic fabrics of the Terylene type, chemical and abrasion resistance can be developed to meet severe corrosion problems.

It is said that the process will enable the production of flattened pipe which will have the same cross-sectional area as a normal pipe, but the resultant tube is flattened to give an oval cross-section. This could be important where space is at a premium (e.g., ships' ventilation ducting which is sometimes bedded in insulating material). Flexo Plastic Industries Ltd., South Chingford, London, E.4.

**EMD 3613** for further information

## Glassed Steel

Greatly increased thermal shock-resistance is claimed for the new Pfaudler glassed steel 59, with an improvement of 30 per cent over conventional glassed steel under the most severe shock treatments caused by the meeting of unexpected or unavoidable temperature differentials. At a temperature of 232 deg. C. it is said to withstand the thermal shock of ice water at 0 deg. C. without any sign of chipping or weakening, and under certain conditions it is claimed that an acid can be raised to 232 deg. C. without damaging the steel.

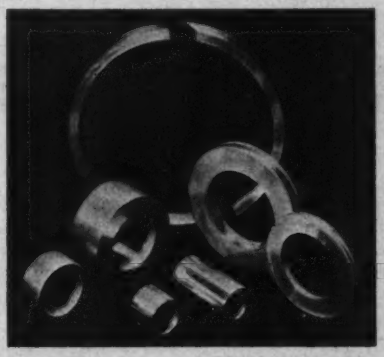
The safe Delta T for the material at a normal vessel operating temperature is 127 deg. C., and 66 deg. C. at the peak operating temperature of 232 deg. C. Its alkali constancy goes up to pH 11 at 100 deg. C. The unusual microstructure, which is responsible for the improved thermal shock-resistance, is said to allow lapping of nozzle faces on all nozzles up to and including 8 in. diameter. Twenty per cent more abrasion resistance is claimed, together with a much longer serving life. Enamelled Metal Products Corporation (1933) Ltd., Artillery House, Artillery Row, London, S.W.1.

**EMD 3614** for further information

## Self-lubricating Metal

A 100 per cent permanently self-lubricating bearing metal in a range of materials known as DEVA alloys is now being produced in this country. These alloys are said to combine the advantages of solid metal and solid graphite without possessing their extreme characteristics. The resulting alloys, it is said, are fully dense, homogeneous solids, having properties which permit the exceeding of service limitations of existing self-lubricating materials; they are also easily machinable.

The metal is recommended for all bearings which must not be lubricated. The graphite lubricating film formed on the contacting surface cannot dry up or flow off during long periods of inaction, as usually happens with oil or grease lubricants. This graphite film is claimed to be permanent and to eliminate the risks of seizure and of wear of costly contacting materials. Deva metal is made in any quantities either as unmachined blanks or as finish-machined bearings, piston



rings, packing rings or slide plates. The Universal Metallic Packing Co. Ltd., Beehive Works, Edderthorpe Street, Leeds Road, Bradford, 3.

**EMD 3615** for further information

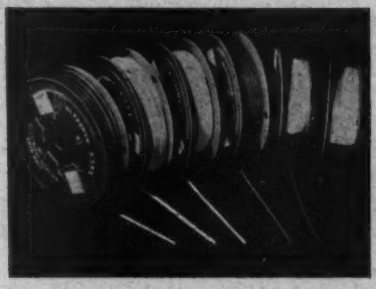
## Aluminium Wool and Filler

With the development of polyester and epoxy type resins in the fabrication of press tools, foundry patterns and matched die moulds, and mould making generally, there is an increased interest in the use of aluminium wool as a thermal conductive medium. The two main functions of the aluminium wool in these applications are to dissipate the exothermic heat generated during the setting of the resin, particularly where thick sections are concerned, and to render the final product as heat conductive as a metal. A typical example of this is in the making of "short life" moulds for injection moulding.

During the setting of the resin internal temperatures can be reached which are sufficiently high to cause scorching and distortion of the mass. The presence of aluminium wool, which has about three times the thermal conductivity of iron and approximately one-third of its weight, ensures that this exothermic heat is conducted away, and thus prevents scorching and improves the dimensional stability of the product. In fabricating a mould, the best results are achieved by packing the cavity with aluminium wool and applying the resin under vacuum, in order to ensure that the fibres of the wool are completely impregnated with the resin. Moulds and other products made from resins containing aluminium wool can be satisfactorily machined if required. Croxton & Garry Ltd., 16-18 High Street, Kingston-on-Thames.

**EMD 3616** for further information

## Electrical Sleeving



Polypenco (p.t.f.e.) thin wall electrical sleeving is now available in twenty-six different sizes, from 0·336 in. inside diameter × 0·015 in. wall thickness to 0·013 in. inside diameter × 0·008 in. wall thickness. It is said to be suitable for use in miniature assemblies, since it has a minimum dielectric strength of 750 volts/mil., a dielectric constant of 2·0, and a surface resistivity of more than $10^{12}$ ohms. It is also claimed to be unaffected by heat and moisture, non-inflammable, chemically inert, and resistant to fungus and sunlight. Polypenco Ltd., 68-70 Tewin Road, Welwyn Garden City, Herts.

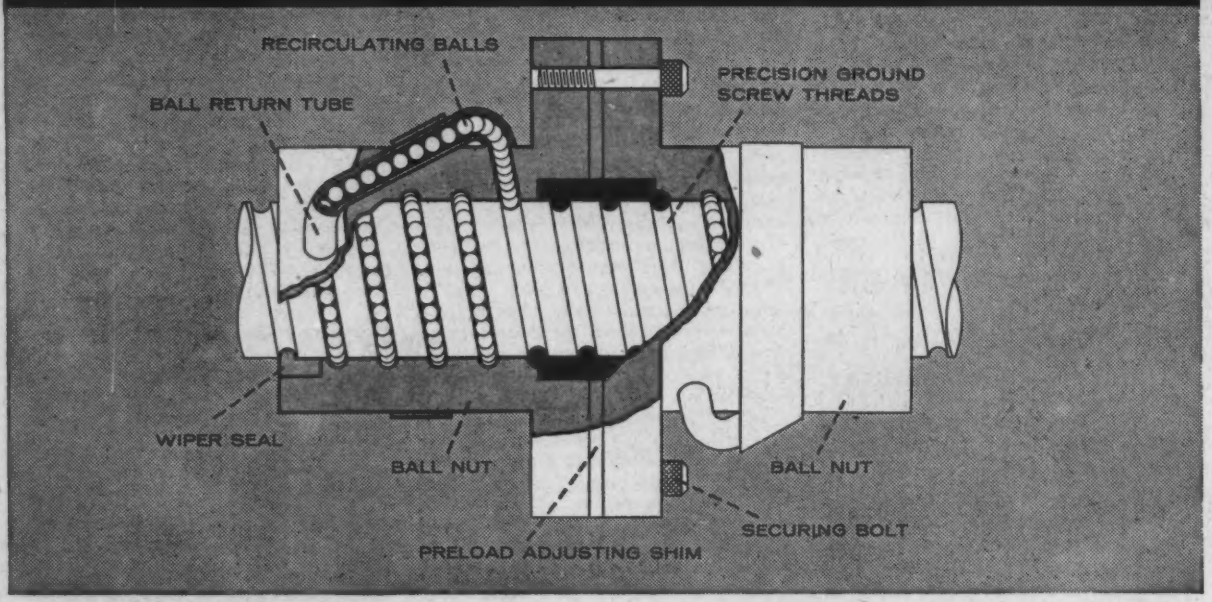
**EMD 3617** for further information

## Lead in Plastic Form

Devcon L is a combination of approximately 94 per cent lead and 6 per cent of a special thermo-setting plastic. Similar in many respects to plastic steel, it has the consistency of putty, and is claimed to be as easy to mould to shape as modelling clay. No heat, pressure or flame is required in its application. Three hours after the addition of a special hardening agent, the mixture becomes a tough, rigid mass very similar in all essential qualities to lead itself. It has excellent adherence to lead, aluminium, bronze, brass, wood, cast-iron, porcelain and concrete. Shrinkage is negligible during hardening and the material can be stored almost indefinitely, since it does not harden with age. E. P. Barrus (Concessionaires) Ltd., 12-16 Brunel Road, London, W.3.

**EMD 3618** for further information

# Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...




# ...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

**Basic design application analysis**

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

**Bristol Siddeley Beaver ball splines** have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

## All-Nylon Conveyor Roller

A new addition to the Handy-Angle range of constructional equipment is a gravity roller in nylon which is said to be

entirely self-lubricating and practically noiseless. It is also said to be very hard wearing. Being lighter than metal wheels, the nylon Flowheels are said to require less gravity "drop" to make them effective. The Flowheel is supplied complete with brass bearing and metal shaft. Handy Angle Ltd., Grand Buildings, Trafalgar Square, London, W.C.2.

**EMD 3619** for further information

## Butterfly Valves

A completely new range of oleo-pneumatic auto-closing butterfly valves has recently been introduced. They are claimed to incorporate several advantages over conventional butterfly and reflux valves, stemming from the asymmetrical blade design and the flexibility of the oleo-pneumatic package operating units.

The torque characteristics of the asymmetric blade make it possible to use the valve as a combined stop and non-return valve. Full flow in the normal direction exerts a closing torque on the blade at all angles from fully closed through approximately 84 deg. to within 6 deg. of the fully open position. At this point the torque reverses and the blade is then held in the fully open position as long as the flow continues in the same direction, until closed by the ram.

If the direction of flow reverses, a closing torque is exerted on the blade at all angles from fully open to fully closed. The blade design also contributes to drop-tight sealing.

The new butterfly valves are available in a range of sizes from 12 to 120 in. in diameter, and larger sizes can be made to order. Boving & Co. Ltd., 41-47 Strand, London, W.C.2.

**EMD 3620** for further information

## Wire-braided Hose

Wingflex is the name given to a type of hose for use with machine and pneumatic tools, earth-moving equipment, compressed air units and similar industrial applications. It is supplied in bore sizes ranging from $\frac{1}{4}$ in. to 2 in. with either re-usable or swaged couplings. The re-usable coupling is invariably supplied with one-braid hose—i.e., where pressures are relatively low—and swaged couplings with two-braid hose where excessive flexing occurs.

The hose consists of a seamless and oil-resistant synthetic rubber tube with a smooth bore, and is designed to operate throughout a range of pressures from 600 to 4,000 p.s.i. in the one-wire braid construction and from 1,000 to 5,000 p.s.i. in the two-wire construction. It is reinforced with high tensile steel wire which is uniformly braided over the lining. The cover is made of synthetic rubber compound (resistant to abrasion, oil, light and flame) and the complete hose is uniformly vulcanised and concentric throughout its length. Goodyear Tyre & Rubber Co. (Gt. Britain) Ltd., 56 Osnaburgh Street, London, N.W.1.

**EMD 3621** for further information

## Heavy-duty Barrier Terminal Block

Designated Type TER, this terminal block has very compact overall dimensions of $2\frac{1}{4} \times 2\frac{1}{4} \times 1\frac{1}{4}$ in. high. Any number of standard two-way terminal blocks of this type can be mounted flush side by side for multi-way connections.

The block consists of a high-grade insulating moulding with two pairs of $\frac{5}{16}$-in. Whitworth nickel-plated brass screws connected by $\frac{1}{4}$ in. wide $\times \frac{1}{4}$ in. nickel-plated copper strips. Two B.A. brass inserts are provided underneath the terminal blocks for fixing purposes.

The terminal block is recommended for voltages not exceeding 650 V., as defined in the regulations for the Electrical Equipment of Buildings, and for a current rating of 100 amps. An N.P.L. test is claimed to have shown that at a current of 74 amps the temperature rise was only 12 deg. C. Breakdown voltage between the terminals is stated to be 7 kilovolts r.m.s. The terminal block weighs $7\frac{1}{4}$ oz. Electrical Remote Control Co. Ltd., Elremco Works, Harlow New Town, Essex.

**EMD 3622** for further information

## Overload Slipping Clutch

The Metastream overload slipping clutch was developed as a safety feature particularly for use on motor-driven rotary transformers for unattended automatic voltage regulation. On these installations a limit switch should cut out the operating geared motor at each end of its possible travel. By the use of these slipping clutches, it is possible for the motor to continue running against some pre-set maximum torque. Metaducts Ltd., Catherine Wheel Road, Brentford, Middlesex.

**EMD 3623** for further information

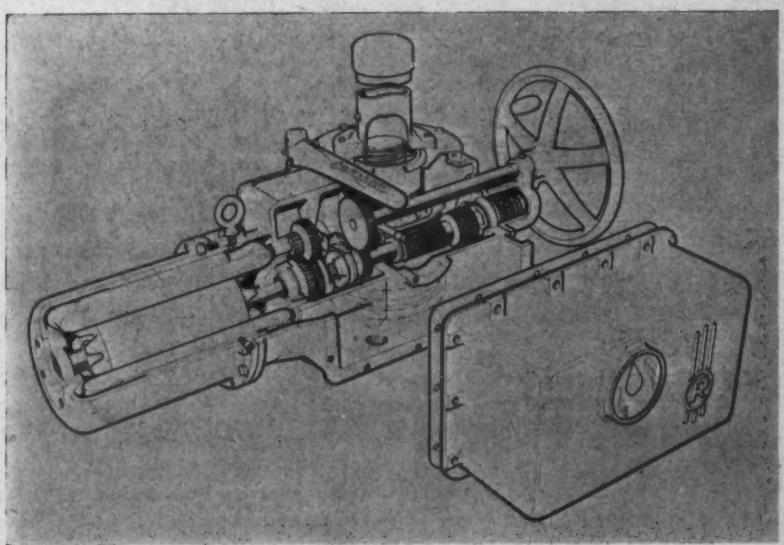
## Range of Valve Actuators

For the operation by remote control of large valves in chemical, oil and processing industries a range of motorised actuators is available which provides torque ratings varying, in eight sizes, from 75 lb. ft. with a maximum thrust rating of 1,200 lb. to 8,000 lb. ft. with a maximum thrust rating of 300,000 lb. The type shown in the illustration is the side handwheel type "A" actuator, which is available for spindle sizes from 3 in. dia. upwards, whereas the top handwheel type "B" actuator covers the range from $1\frac{1}{4}$ in. dia up to $2\frac{1}{4}$ in. dia.

The actuators are provided with geared limit switches, the drive being through spur and worm gearing from the output shaft. The switches can be independently adjusted to operate at any point during valve travel, and are claimed to operate satisfactorily in damp and dusty atmospheres. A torque limit switch is also provided. All actuators can be fitted with electrical remote position indicators which comprise three separate units—the transmitter, the stabilised power pack and the receiving instrument.

The actuator normally incorporates a three-phase squirrel cage motor which runs in both directions to open and close the valve. Rotork Engineering Co. Ltd., Bath, Somerset.

**EMD 3624** for further information



EMD 3518 for further information

When did *you* last see a Dutch interior? Never mind! The point is that there's an art to protecting the interiors of tanks. And Ensecote has it. *Any* size of tank. *Any* sort of liquid practically. Ensecote protective linings are easily cleaned and sterilized; completely odourless, tasteless, and economical to install (larger vessels can be lined on the spot). Ensecote protective linings add years to a tank's life.

# ENSECOTE *Lithcote* PLASTIC LININGS

*For literature and technical advice on linings, and on tank fabrication, write to:* NEWTON CHAMBERS & CO. LTD., THORNCLIFFE, SHEFFIELD, ENGLAND

*Agents in Belgium, France and Holland:* FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, S.A., TRAZEGNIES, BELGIUM

## Water Meter

The recently introduced JSM meter is claimed to operate satisfactorily for very long periods under arduous conditions with minimum maintenance.

Although of a basically rotary-piston type, an important difference is that the working chamber has its axis in line with the direction of flow. This entails six fewer right-angle changes in fluid flow direction and permits a very compact design without sacrificing maximum capacity. It is suitable for installing in horizontal or vertical mains.

The working chamber is contained in one half of the two-section brass body-housing, which consists of two cup-shaped stampings screwed together at their largest diameters and positively sealed with an "O" ring. All gears are in moulded graphited nylon to reduce friction and eliminate corrosion.

Registration may be in gallons or cubic metres and no modification is required to fit the optional disc-type non-return valve or return-flow filter. All types of international standard body lengths and end threads can be accommodated. George Kent Ltd., Luton, Beds.

**EMD 3625** for further information

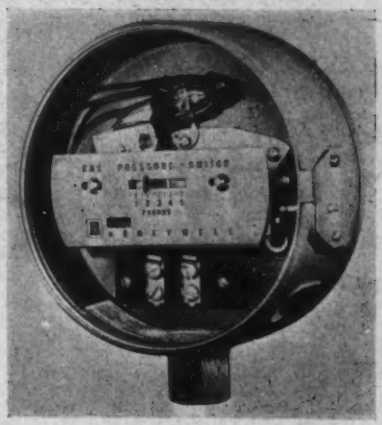
## Gas Pressure Switches

New gas pressure switches have been introduced as part of their range of simple non-indicating industrial controllers by Honeywell Controls Ltd.

Designed for heavy duty under arduous operating conditions, these diaphragm-actuated mercury switch controllers can be used as safety cut-off switches or simple pressure controllers for both hazardous and non-hazardous gases.

They feature a seal-off diaphragm which prevents gas from entering the switch chamber should the main diaphragm be ruptured. This, together with the high overload capacity, confers a high degree of safety operation.

With non-hazardous gases, the switches can be used as differential pressure controllers since the seal-off chamber becomes the low pressure side.



Pressure ranges from ½-5 in. water to 10-100 p.s.i. are available. Switching action is SPST, make or break on pressure rise according to model. SPDT versions are available.

A lock-out feature—optional on some models, standard on others—prevents recycling when the pressure returns to preset limits, having once broken circuit. This feature can be adjusted to eliminate the lock-out if desired. Honeywell Controls Ltd., Ruislip Road East, Greenford, Middlesex.

**EMD 3626** for further information

## Flexible Coupling

The Quadriflex coupling, a recently introduced device for withstanding all types of misalignment and end float, consists of two flanges and a two-piece flexible rubber sleeve. The teeth of the sleeve halves lock into the teeth of the flanges without clamps or screws and tighten under torque to provide smooth transmission. The coupling is claimed to have exceptional flexibility, 15 deg. at peak torque, combined with the ability to absorb vibration and shock.

The coupling is said to be easy to install and is unaffected by abrasives, dirt and moisture. As rubber is the torque transmission medium, there is no metal-to-metal contact and therefore no need for lubrication. Operation is noiseless.

The Quadriflex coupling is designed to provide all four degrees of flexibility, angular misalignment up to 1 deg. and parallel misalignment up to $\frac{1}{16}$ in. R. & J. Dick Ltd., Greenhead Works, Glasgow.

**EMD 3627** for further information

## Miniature Syncroverter Switch

A new low noise chopper, the C1410, is a miniature, precision, non-resonant inverter with an external coil. It is claimed to be ideally suited for dry circuit applications.

The C1410 has the following characteristics: Frequency range, 0-1,800 c/s. Temperature range, −65 deg. C. to + 125 deg. C. Operating characteristics at 6.3 volts r.m.s., 400 c/s, 25 deg. C. Dwell time, 170 deg. + 15 deg. Dissymmetry, 15 deg. max. Phase lag, 64 deg. ±10 deg. Noise (at one megohm), measured through amplifier with bandpass of 8 to 1,000 c/s, is less than 100 microvolts peak to peak, and 10 microvolts r.m.s.

The switch is offered with SPDT Switch action and with contact ratings up to 10 volts 1 m.a. It is approximately 1¼ in. high and ¼ in. dia. Elliott Brothers (London) Ltd., Relay Division, 70 Dudden Hill Lane, Willesden, London, N.W.10

**EMD 3628** for further information

## Low Force Unitor

For use with rack-mounted electronic equipment where electrical connections are required at the rear of sub-units, the Ferranti low force Unitor is announced. It can also be used with either free plug or free socket.

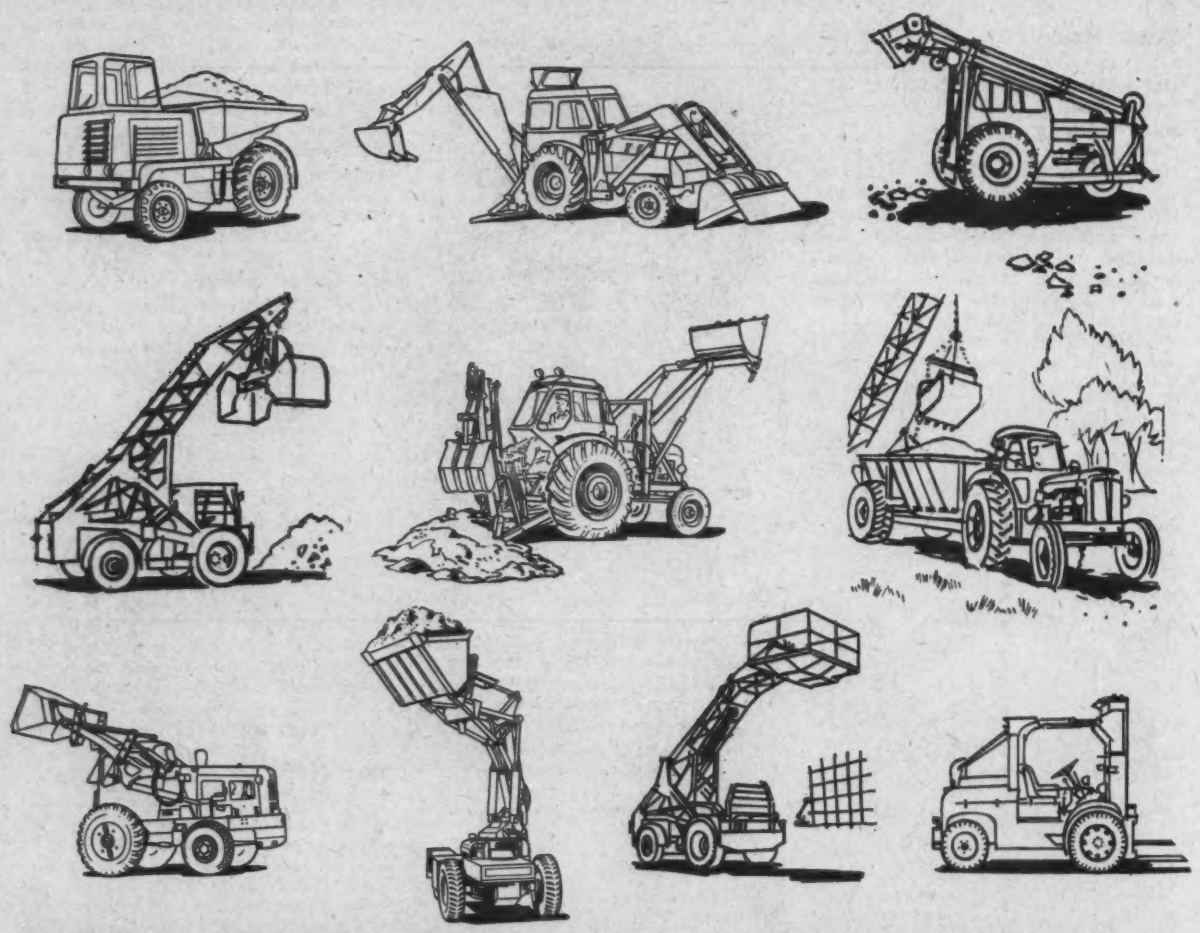
The low nominal insertion force of 4 oz. per pole is stated to be due to the unique construction of the socket clips, the jaws of which are actuated by independent springs. An important feature of the design is said to be the fact that the total insertion force is in direct proportion to the number of poles. The withdrawal force is approximately two-thirds of the insertion force and there is considerable tolerance to misalignment. At present, 35, 70 and 91 pole types of the Unitor with silver-plated contacts are available. Ferranti Ltd., Ferry Road, Edinburgh.

**EMD 3629** for further information

## Spring Pin

A new range of self-locking carbon-steel spring pins known as Sel-lok is announced. They are said to be ideal for the type of application illustrated. All that is necessary to fit the pin is to drill a hole through the component and shaft and drive the pin home, tapping or reaming being entirely eliminated. One of the advantages claimed for the Sel-lok is that it can be removed and refitted many times without damage to the pin or the assembly. In certain applications the pins are stated to have a cushioning effect which, if not required, can be reduced or removed entirely by inserting a further spring pin inside the first. The sizes range from $\frac{1}{16}$ in. dia. to ½ in., in a large number of lengths. Unbrako Socket Screw Co. Ltd., Burnaby Road, Coventry.

**EMD 3630** for further information



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## Extensible Hydraulic Link

The Hi-Flex extensible hydraulic link is designed for use in conjunction with flexible pressure pipes, so that large equipment may be articulated or flexed without the disadvantages of looped hoses which might catch on obstructions. In essence, it consists of a tubular member capable of being expanded and contracted axially, and employs a hydraulically balanced mechanism which enables these movements to be carried out while fluid at high pressure is going through the appliance. The resistance to movement is low so that little energy is absorbed when relative movement takes place between the end attachments.

In its present form it is designed with plain tube ends, but could easily be produced with standard male or union ends. The standard model is adapted for ¼-in. feed lines. Its overall length extended is 18¼ in., and fully retracted 15 in., but this travel can be extended for special services. The designed maximum working pressure is 3,000 p.s.i. The unit is said to be leak-proof, and capable of functioning for extended periods before replacement of seals is required, which operation can be conveniently carried out. Made in mild steel and plated, the component is so designed that seals and moving parts may be easily inspected and replaced as desired. This link has been made in one size only, but can be adapted for almost any size or application. It is not intended to operate as a ram. B.T.R. Industries Ltd., Hose Division, Vincent House, London, S.W.1.

**EMD 3631** for further information

## Wheel Castor with Brake

The Autoset braked wheel castor is fitted with expanding brakes within the wheel. This brake can be operated in conjunction with an adjacent castor by the depression of a vertical pin by means

f an Ackerman control. Malleable castings are used throughout on the 8 in. dia. wheeled model, but aluminium alloy castings are used for the 10 in. and 16 in. dia. wheel models. Autoset (Production) Ltd., 74-76 Stour Street, Birmingham, 18.

**EMD 3632** for further information

## Hydraulic Screw Pumps

The new Telesig range of positive-displacement pumps are simple in construction. Delivery is effected by means of three parallel screws engaging each other, the power-driven central screw driving the two side screws. The profile of the screws has been specially developed to provide a continuous seal and a maximum efficiency. The pumps are self-priming and delivery is claimed to be free from pressure pulsation.

There are three basic types of Telesig pump available: for low pressure of up to 300 p.s.i., for medium pressure up to 1,000 p.s.i. and for high pressure up to 2,500 p.s.i. Forty-two sizes are available, covering a wide range of capacities. Telehoist Ltd., Manor Road, Cheltenham, Glos.

**EMD 3633** for further information

## Machine Tool Mobility Device

The Vulca-Skate is an ingenious yet simple device that enables machine tools already fitted with bolts in their feet, for

use with Vulcascot anti-vibration mountings, to be easily moved about the workshop. The Vulca-Skate is simply a heart-shaped cast trolley base to which are fitted three castors. The procedure involved consists of raising the machine tool by means of the levelling screw until there is room for the Vulca-Skate to be wheeled underneath it. The machine tool is then lowered on to the Vulca-Skate, when it can then be moved to the new position.

Vulca-Skates have a safe load capacity of 1½ tons and are provided with ball bearings for the castor wheels. Vulcascot (Gt. Britain) Ltd., 87/89 Abbey Road, London, N.W.8.

**EMD 3634** for further information

## Bonded Seals

Dowty bonded seals are designed for leakproof face-to-face sealing against water, gases, oil and a wide range of other fluids at pressures up to 10,000 p.s.i. Each seal consists of a synthetic rubber sealing member heat and pressure bonded to a cadmium-plated steel ring. The sealing action is initiated by deflection of the moulded rubber lips when the bonded seal is assembled. When fluid pressure is applied, this acts upon the flexible lips, increasing the intensity of the sealing contact against the adjacent faces.

The seals are particularly suitable for the sealing of screwed fastenings, and for use between components connected by parallel screw threads. Typical applications include the assembly of pipe, tube and hose fittings to units having threaded connections such as pumps, valves and hydraulic cylinders, also the sealing of parallel threaded plugs in tapped holes, and screws and bolts through panels, bulkheads and tank walls. No special machining or grooves are required, and it is claimed that bolting torque is reduced and maintenance minimised. Hydraulic Components Co., 5 Manor Gardens, Scarborough, Yorkshire.

**EMD 3635** for further information

## Grease Lubricator

The "SG", a new lubricator for self-levelling greases, has a positive action and is claimed to show a considerable first-cost saving against all-purpose grease lubricators of more complicated design.

The new lubricator is compact but robust, has a grease capacity of 8 lb., and is fitted with up to six outlet connections. It can be supplied with a plain shaft drive, or the drive can be arranged through a sprocket, pulley or ratchet. Alternatively, the lubricator can be supplied with its own worm or ratchet gearbox in order to take advantage of higher driving speeds.

A complete installation, comprising the lubricator directly coupled to a fractional h.p. geared motor and mounted on a mild steel baseplate, can also be provided. Wakefield-Dick Industrial Oils Ltd., Castrol House, Marylebone Road, London, N.W.1.

**EMD 3636** for further information

EMD 3520 for further information

# THIS IS NOTHING TO WHAT GOES ON INSIDE A

# BULLOWS NOPUMP

## SPRAY BOOTH

***ALMOST ENTIRELY ELIMINATES MAINTENANCE***

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In this new type of Water-Wash Spray Booth the exhaust air travels at very high velocity over the water surface entraining water. The air/water mixture, moving through controlled changes of direction, provides the scrubbing action.

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This Booth was started up on production on 1st March, 1959, and has operated two nine-hour shifts on continuous painting of agricultural machinery. When last examined, there was an average depth of silt of 6 inches over the entire water tank bottom, an area of 290 sq. feet. A further 4 inches, making 10 inches in all, can be accommodated before cleaning is essential. After 1 year's operation, the fan and ducting were barely discoloured, the only maintenance cost being cleaning the floor inside the booth, routine greasing of bearings and similar preventive maintenance.

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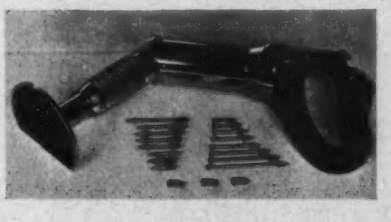
## Overhead Projector

The Transpaque overhead transparency projector gives a lecturer many advantages over blackboard or lantern slide presentation. He can face his audience throughout his lecture, using previously prepared 10 x 10 in. transparencies in single or overlay colours. Alternatively, he can use a preprinted roll of one colour foil on which typewritten notes and diagrams are laid out in sequence. He can also make spot notes on a conveniently placed strip of clear foil with a grease pencil, the image of which is projected on the screen as he writes. The projector gives a large, clear picture in a fully lighted room. Lawes Rabjohns Ltd., Abbey House, Victoria Street, London, S.W.1.

**EMD 3637** for further information

## Cartridge Hammer Gun

The Bossong cartridge hammer gun enables bolts, nails and screws of varying lengths and size to be instantly fixed into



concrete, steel, brickwork, breeze blocks, etc., with a minimum of effort. In addition, Whitworth screw-headed studs are supplied for proud fixings. The fixings can be fired directly into the basic materials, and the gun is fully automatic and cartridge-ejecting, whether loaded or spent. It does not require a licence to operate. It would appear to have a number of useful applications in engineering, particularly in that a special muzzle has been devised which is claimed to ensure accurate fixing into slotted angle "T" sections and narrow slotted steel lengths. Bossong Ltd., 3-4 Duxon Turn, Maylands Avenue, Hemel Hempstead, Herts.

**EMD 3638** for further information

## Portable Measuring Instrument

The Elcotector Mark II is a fully portable battery-operated instrument designed to carry out a wide variety of measurements in a non-destructive manner. Its primary use is for all types of coating measurements on components. In addition, it is capable of measuring the thickness of most metallic and non-metallic foils both in the static and moving state, and can be applied to a production run to give continuous readings. Other duties include surface crack detection, comparison of hardness of steel components, measurement of variation between different types of alloys, etc.

The instrument operates on the principle that electrical characteristics of a coil are influenced in proportion to its proximity to a metal surface. The coil in this case is situated in the head of the probe which is presented to the surface under test. Two types of probe are available for hand checking purposes, and for continuous strip measurement special probes can be produced capable of accommodation on any specific machine. Hollow cup or pot coils are provided for repetitive hardness measurement of small tools such as drills, plug gauges, taps, steel balls, etc.

The unit employs a printed circuit and is fully transistorised. It is housed in a black laminated plastic case approximately 8 x 6 x 4 in., and is complete with leather carrying case with provision for shoulder strap. Weight with batteries, lead and probe is 7 lb. 13 oz.; complete with case, 11 lb. 10 oz. Power is provided by ten dry batteries giving an average life of 200 hours at approximately 6 hours a day. If required, a mains power unit can be incorporated. East Lancashire Chemical Co. Ltd., Fairfield, Manchester.

**EMD 3639** for further information

## Portable Drawing Device

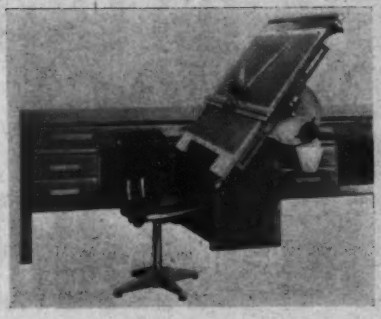
One of the more ingenious pieces of portable drawing equipment is the Quickdraw transparent template. Fastened to a pantograph fixed to the base of a folder, it enables drawings and perspective sketches to be rapidly and accurately produced without the need for table or drawing board. The transparent template is bevel edged and accurately marked in inches and millimetres, the outside edges being cut to correspond with the most commonly used angles. Particularly ingenious is the system which allows

cross hatching to be effected without the need to estimate the distance between the lines. Additional scales which still further assist the designer are those for drawing ellipses of any size, process and planning method symbols and an accurate protractor. Cut-out circles incorporated in the main protractor are particularly valuable in preparing theoretical electrical circuit diagrams. The folder, for which additional pads of drawing paper are available, is 14 in. square with a $\frac{1}{16}$-in.-thick base covered in strong rexine. Quickdraw Co. Ltd., 127 Gunnersbury Avenue, London, W.3.

**EMD 3640** for further information

## Cantilever Drafting Unit

The Arclight cantilever drafting unit enables the draughtsman to work without impediment to his legs and feet. It has



been designed to accommodate a Mason Minor drafting stand with any of several types of drawing-board assemblies, according to choice, and can be used as a single unit installation in a small office or as an addition to existing equipment. The horizontal cantilever arm is of tapered section fabricated from 16-gauge mild steel sheet suitably reinforced, and is secured by a supporting section consisting of 2 by 2 by $\frac{1}{4}$in. mild steel angle rigidly braced. There is an overhang at the front and back of the cabinet top, and the cantilever arm is finished in stoved enamel. E. N. Mason & Sons Ltd., Arclight Works, Colchester.

**EMD 3641** for further information

## Plan Printer and Developer

A continuous plan printer and developer known as the Triumph is designed for fast and economical production of first quality dyeline (diazo) prints. The working width of this machine is 45 in., so that full-width 42-in. sensitised materials may be used, with automatic double-sided development. Other automatic features are: washing and cleaning of the developer unit; blanket control and tracking; stacking of any size of print up to 40 x 40 in.; constant level developer (patent applied for, and voltage compensation within $\pm 20$ volts.

The unit delivers prints flat and dry of any length and up to 42 in. wide, and prints at speeds of up to 30 ft./min. with a 3-kW. tube and approximately 18 ft./min. with a 2-kW. tube. It will handle all types of materials from lightweight airmail up to heavy weight paper and opaque cloth, and does not require ducting. Its overall dimensions are length 6 ft., height 4 ft and depth 6 ft. E. N. Mason & Sons Ltd., Arclight Works, Colchester, Essex.

**EMD 3642** for further information

**FOR MORE INFORMATION**
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

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# GOOD PLATING STARTS ON THE DRAWING BOARD

Because the shape of the work affects the way in which nickel and chromium are electro-deposited, early attention to details of design helps the plater to help *you*. It enables him to meet more economically the requirements of British Standard 1224:59. Then you can apply the appropriate 'Label of Plating Quality' to your product.

## What is British Standard 1224:59?

In addition to clauses covering adhesion and other aspects of processing, BS 1224:59 calls for minimum thicknesses of nickel for various conditions of service because the nickel provides most of the resistance to corrosion. The Mond Label of Plating Quality can be attached to plating which meets these standards.
The specification normally applies only to those parts of the significant surface which can be touched by a 1-in. diameter ball. Where a comparable nickel deposit is required in other areas, such as corners and recesses, manufacturers should come to a special arrangement with the plater.

| Service Conditions and colour of label | Material | Designation | Nickel Thickness Minimum Inch |
|---|---|---|---|
| Severe *Red Label* | Steel<br>Copper or Brass<br>Zinc Alloy | Ni 12S<br>Ni 6C<br>Ni 10Z | 0.0012<br>0.0006<br>0.0003 Cu +<br>0.0010 Ni |
| Moderate *Blue Label* | Steel<br>Copper or Brass<br>Zinc Alloy | Ni 8S<br>Ni 3C<br>Ni 6Z | 0.0008<br>0.0003<br>0.0003 Cu +<br>0.0006 Ni |
| Mild *Green Label* | Steel<br>Zinc Alloy | Ni 4S<br>Ni 3Z | 0.0004<br>0.0003 Cu +<br>0.0003 Ni |
| Chromium thickness 0.00001 in. minimum | | | |

*Note that some of these figures are different from BS 1224:53 now obsolete.*

**FOR FURTHER INFORMATION**

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## Plan File Unit

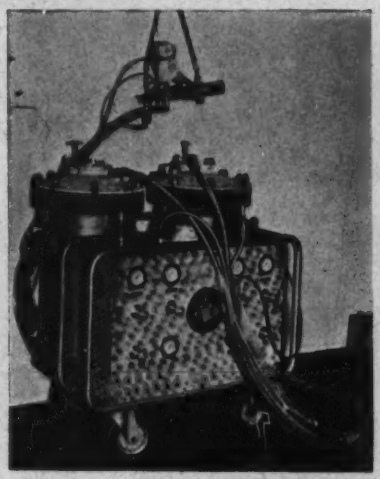
Simplanfile is a vertical cupboard unit that has double the capacity of a six-drawer plan file yet takes only half the floor space. The plans are so arranged in it that the reference numbers are always at eye-level. Approximately 1,000 tracings can be accommodated—500 on each of the two sliding bar devices. These are subdivided so that only about 250 drawings are suspended one against the other.

Filing and removal are said to be simplicity itself. To remove a plan the procedure is (1) the sliding bar is pulled out; (2) the telescopic threading pins are extended; (3) the drawing released, and (4) the pins opened and the drawing removed. Considerable space saving is achieved by means of a rolling shutter door, which disappears into the cabinet when opened and provides a dustproof door when closed. The unit is in striped sapele mahogany, and is suitable for drawings up to antiquarian size, although units can be supplied to special order for drawings up to double elephant size.

Plans to be stored in the Simplanfile are first provided with a carrying tape in which holes have been pre-punched. This operation is handled by the Simplanfile edge binding unit with punched suspension tape attachment. This unit can also be used for strengthening the edges of plans, drawings, maps, documents, etc. Dargue Brothers Ltd., New Simplon Works, Halifax, Yorks.

**EMD 3643** for further information

## Spraying Machine

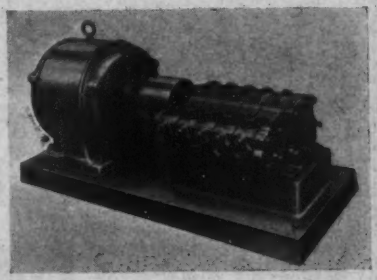


An M.A.S. fibre/resin spraying machine is available combining in an enclosed unit the multi-component spray gun with a small fibre-cutting mechanism. This machine will be found useful where the two larger types, SP.VI and BK.III, cannot be fully utilised or where they are not convenient on account of restricted space. Metropolitan Plastics Ltd., Glenville Grove, Deptford, London, S.E.8.

**EMD 3644** for further information

## Hydraulic Pump

A new development in high-speed hydraulic pumps fulfils the requirements of mining and general engineers who need a high-pressure pump of very small capacity. The pump is of unit construction, and is available with from three to six cylinders. Each cylinder has an output



of 0·6 imperial gal./min. Delivery pressure is 1,000 p.s.i.

The eccentric shaft of the pump, which is mounted on roller bearings, is coupled directly to the motor, which runs at a synchronous speed of 11,000 r.p.m. through a flexible coupling. The pumps are suitable for operation with water, water-soluble oil mixture or hydraulic oil as the working medium, and the design can be adapted for use with other liquids. The units can be provided with spring-loaded relief valves, or alternatively with automatic unloading valves which enable them to run light when operating against closed stop valves. Joseph Evans & Sons (Wolverhampton) Ltd., Frederick Street, Wolverhampton.

**EMD 3645** for further information

## New Publications and Technical Literature

**The United Kingdom Atomic Energy Authority:** Catalogue, in two parts, of the radioactive products offered for sale through the Authority's Radiochemical Centre—(1) "Radioactive Chemicals", dealing with the primary isotopes and labelled compounds which are of interest to all who use radioactive tracer methods, and with radioactive pharmaceuticals; (2) "Radioactive Sources", concerning the sealed radioactive sources and appliances for radiotherapists and industrial users of ionising radiations. The Radiochemical Centre, Amersham, Bucks.

**EMD 3646**

**Plenty & Son Ltd.:** Illustrated leaflet describing the complete range of Duplex filters (from ¾ to 30 in. bore), which are so designed that the filter baskets can be cleaned in turn without interruption to continuous flow. Eagle Iron Works, Newbury, Berks.

**EMD 3647**

**Expanded Rubber Co. Ltd.:** Revised booklet, with full-scale illustrations, giving details of gaskets and tubes made from Rubazote, which is a soft expanded rubber in which the individual cells are sealed one against the other. Mitcham Road, Croydon, Surrey.

**EMD 3648**

**Johnson Matthey & Co. Ltd.:** Well-illustrated brochure containing details of a technique for the production of joints in copper water service systems by means of low-temperature silver brazing. 73-83 Hatton Garden, London, E.C.1.

**EMD 3649**

**Prat-Daniels (Stroud) Ltd.:** Folder containing illustrated leaflets describing the firm's ranges of dust collectors, spark arresters and centrifugal fans.

**EMD 3650**

**J. H. Fenner & Co. Ltd.:** Eighty-page catalogue containing full details of the Spacesaver wedge-belt drives.

**EMD 3651**

**Brown, Lenox & Co. Ltd.:** Booklet (26 pages) of reference for users of steel castings.

**EMD 3652**

**Imperial Chemical Industries Ltd.:** Brochure giving details of Silcoset silicone rubbers, which, when mixed with a curing agent and left to set at room temperature, form flexible materials resembling natural rubber in many respects but possessing, in addition, the special characteristics of silicones.

**EMD 3653**

**General Electric Co. Ltd.:** Two leaflets —(1) describing vacuum induction furnaces suitable for melting and casting metal gas free; (2) indicating types of "cold retort" vacuum resistor furnaces that are available. **EMD 3654**

**Sheffield Wire Rope Co. Ltd.:** Revised 70-page catalogue listing the company's ropes in accordance with the revised British Standards, together with copious introductory notes. **EMD 3655**

**Firth Cleveland Pumps Ltd.:** Leaflet illustrating, in graph form, technical data on the company's range of single-stage self-priming universal drive centrifugal pumps. **EMD 3656**

**B.A.L. Ltd.:** Booklet of data on Polypac packings, oil seals and precision rubber mouldings. **EMD 3657**

**Copper Development Association:** Booklet (78 pages) intended as a general guide to the applications of copper.

**EMD 3658**

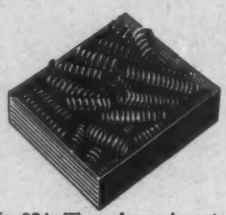
**Stuart Davis Ltd.:** Brochure describing the Red Ring range of air control valves and cylinders. Much Park Street, Coventry, England. **EMD 3659**

# THAT *Experimental Spring* YOU WANT IS WAITING FOR YOU IN THIS BOX...

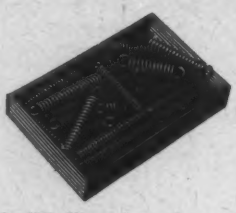
No. 1217. One gross Assorted Springs. A complete Garage Service Kit. 42/- each.

## If not, try another box in the Terry Assorted Springs range

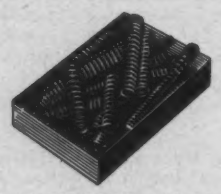
No. 1200. Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. 13/6.



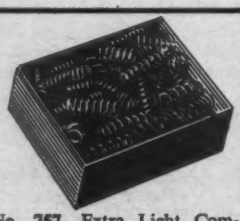
No. 98A. Three dozen Assorted 1" to 4" long, ¼" to ½" diam., 19G to 15G. 5/6.



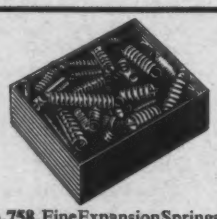
No. 753. Three dozen Assorted Light Expansion ¼" to ½" diam., 2" to 6" long, 22 to 18 S.W.G. 10/6.



No. 760. Three dozen Assorted Light Compression Springs. 1" to 4" long, 22 to 18 S.W.G., ¼" to ½" diam. 6/6.



No. 757. Extra Light Compression, 1 gross Assorted, ¼" to ½" diam., ¼" to 2½" long, 27 to 19 S.W.G. 15/-.



No. 758. Fine Expansion Springs. 1 gross Assorted ⅛" to ⅜" diam., ¼" to 2" long, 27 to 20 S.W.G. 15/-.

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# News of Industry

Excessive vibration and noise can cause harm to both machines and operators, and continual research is necessary in order to locate and isolate damaging vibrations. **Cementation (Muffelite) Ltd.** are concerned with vibration insulators and anti-vibration mountings of all sizes, and their laboratory is equipped to undertake any test necessary to confirm the suitability of insulators and anti-vibration mountings in various environments.

A new research centre for **Hawker Siddeley Industries Ltd.** is to be established at Stockport to provide basic research and development facilities in a single, compact establishment for the heavy diesel engine companies of Mirrlees, Bickerton & Day Ltd. and The National Gas & Oil Engine Co. Ltd.

A recent marine application of V-belts is in the new Norwegian ice breaker and salvage vessel *Herkules*, which uses 24 **Goodyear Tyre and Rubber Co.** V-belts to transmit 1,100 b.h.p. from each of four engines to the propeller shaft. The belts withstand a considerable amount of reverse bending due to jockey pulleys riding on their outward surface, and allow utilisation of relatively lightweight high-speed engines with a substantial elimination of engine vibration.

**Bristol Aircraft Ltd.**, a member company of British Aircraft Corporation, are now offering to industry specialised consultative, design and engineering services based on their extensive experience in electronic instrumentation.

Over 2,000 tons of steelwork have been detailed, fabricated and erected for the A.G.C. reactor at Windscale, for the U.K.A.E.A., by **Fleming Brothers (Structural Engineers) Ltd.** In the reactor containment building the rocker bases for the sloping columns are designed to accommodate an expansion and contraction cycle of 1 in. The positioning of the refuelling machine girders (carrying 400 tons) entailed a transverse tolerance of 0·02 in. across the full width of the plate, and a vertical step not exceeding 0·01 in. between adjacent plates at the joints.

By the acquisition of Dawe Instruments Ltd., of Ealing, the electronics division of the **Simms Group of Companies** (recently augmented by the acquisition of Cawkell Research & Electronics Ltd.) is able to provide complete coverage on component manufacture, applied electronics and instrumentation.

The radio telescope at Bonn University Observatory will shortly be used for an intensive investigation into the temperature prevailing in interstellar gas. This new outer-space research programme provides an application for travelling wave tubes manufactured by **English Electric Valve Co. Ltd.**

An electrical differential is used in a 4-ton travelling jetty crane built by **Stothert & Pitt** and supplied to Tunnel Portland Cement Co. Ltd. The crane works along a curved track on four two-wheel bogies. One bogie on each side is driven by a **Crompton Parkinson** 25-h.p. weatherproof motor through worm gearing, and the differential takes the form of cascade connection of the motors, combined with Allen West control gear.

An optical design group is to be set up at the Imperial College of Science and Technology, London, with the support of **D.S.I.R.**, to develop new advanced methods of lens design.

A one-year post-graduate course in automobile engineering has been established at Cranfield, in Bedfordshire, in association with **The College of Aeronautics**, commencing October, 1960.

The new factory of **Aero Pipe & Glass Co. Ltd.** was recently opened at Yiewsley in Middlesex. Of particular interest is the new Ransburg paint installation, which represents the latest development in electrostatic paint processing.

At the recent opening of the Maydown works of the **Du Pont Co. (U.K.) Ltd.**, in Northern Ireland, it was indicated that products other than neoprene synthetic rubber may eventually be made there. Although the plant was originally designed for production of 50,000,000 lb. of neoprene a year, a 20 per cent increase in capacity has been announced, reflecting the growing demand for this material in the European market. Neoprene is a multi-purpose synthetic rubber which has a multitude of end-uses. It is not just a substitute for natural rubber, although it matches it closely in physical characteristics. Its main attribute is superior resistance to attack from weathering and sunlight, oil, heat and chemicals, which rapidly deteriorate ordinary rubber. In addition, neoprene does not support combustion. Dissolved in a solvent, it is also widely used as an adhesive.

Sir Charles Goodeve, O.B.E., D.Sc., F.R.S., is to succeed Mr. W. F. Cartwright as president of **The Iron and Steel Institute**. He will be in office at the time of the Institute's proposed Special Meeting in the U.S.A., in October 1961.

A new plant for the continuous pickling of high-quality silicon steel strip for the electrical industry has been installed by **Kestner Evaporator & Engineering Co. Ltd.** in the Brierley Hill works of **Richard Thomas & Baldwins Ltd.** The plant is made from Keebush material, which has high resistance to the corrosive effects of the sulphuric and hydrofluoric acids.

## MEETINGS

The **Institution of Production Engineers** is organising a National Conference, to be held in Brighton from October 12-14, 1960.

The **International Synthetic Rubber Symposium and Exhibition** will be held at Church House, Westminster, from October 11-13, 1960.

Already acknowledged as an art, photography is being increasingly recognised as an essential tool of industry, commerce, science and the professions. To recognise its versatility and many facets, the **Industrial Photographic & Television Exhibition**, at the Royal Albert Hall on November 21, provides a common meeting ground.

The **Second International Trade Fair** at Brno, Czechoslovakia, will be held from September 11 to 25, the range of exhibits including products of the engineering and metallurgical industries as well as raw materials and semi-products related to these industries; special attention will be paid to machine tools.

The fifth Reactor School course on the control and instrumentation of reactors will be held by **U.K.A.E.A.** from September 12 to 13, 1960, at Durley Hall, Bournemouth, Hampshire.

Ergonomics is to be the subject of a conference in London organised by the **Department of Scientific and Industrial Research**, from September 27 to 29.

In collaboration with the **British Welding Research Association**, the **Institution of Mechanical Engineers** is to organise a symposium on "Pressure Vessel Research towards Better Design" in London on January 18, 1961. Papers will include comparisons of continental and British practices and design codes, and an outline will be given of some of the difficulties associated with design of pressure vessels for low-temperature operation. The 1960 Autumn Meeting of the **Institute of Welding** will be held between November 1 and 3 in London, and will be devoted to the metallurgy of welding and brazing.

## FILMS

**General Electric Co. Ltd.** have produced a sound film entitled *Infra-red Heating in Industry*. This 16-mm. film is in colour, runs for 20 minutes and is available on free loan.

Part 1 of a film entitled *Hinkley Point* has been produced for the **English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group**. It is a coloured sound film, 35 or 16 mm., with a running time of 29 minutes, and is available on free loan.

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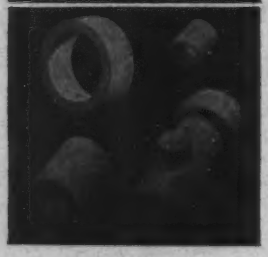

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